XIA LLC

UltraLo-1800 Alpha Particle Counter

User's Manual

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I. Conventions of the Manual

Before covering any technical issues, there are a few conventions used in this manual that should be discussed.

First, when discussing interaction with the software, “click” will always mean “left-click”. Whenever right-clicking is required, it will be denoted “right-click”. Additionally, when discussing the software interface, menu names will be in italics, such as *File*, and options under the menu will be in quotations: “Exit”.

In the Theory of Operation section, important new terms will be in bold: **anode**. This is to distinguish them as terms that will be reused.

The manual has frequent references to other sections, these references will be actively linked (so clicking on them in the PDF will take you to the correct section), and will be bolded and in light blue: **Theory of Operation**. In contrast, hyperlinks that will open an e-mail client or internet browser are, per the normal convention, underlined and in blue: support@xia.com. Finally, references to figures aren’t distinguished from normal text, but will link to the figure.

II. Theory of Operation

A. Operation of the UltraLo-1800

1. Synopsis

The diagram of the UltraLo-1800 in Figure II-1 shows its major components. It is basically a specialized ionization counter comprising an **active volume** filled with argon, a lower grounded electrode that is a conductive tray holding the **sample** (called the **sample tray**) and an upper pair of positively charged electrodes. Of these two electrodes, the **anode** sits directly above the sample, while the **guard** electrode surrounds and encloses the anode. Both electrodes are connected to charge-integrating preamplifiers whose output signals are digitized and then processed by a digital pulse shape analyzer.

An alpha particle emitted from the sample (α_S) creates an **ionization track** of argon ions and electrons. As the electrons drift in the counter's electric field, they induce a time varying charge on the anode that is seen as a current by the preamplifier, which integrates it to produce an output **pulse** that is digitized and then analyzed to extract its risetime, amplitude and shape. Similarly, ionization tracks produced by alpha particles emanating from other counter components (e.g. the anode (α_a) and the sidewalls (α_W)) also produce digitized output pulses in the anode or guard processing channels or both. The UltraLo-1800's geometry is designed specifically so that the output pulses associated with these different points of alpha particle emanation are substantially different – having, specifically, different risetimes, amplitudes and shapes. The UltraLo-1800's analysis software uses this shape information to

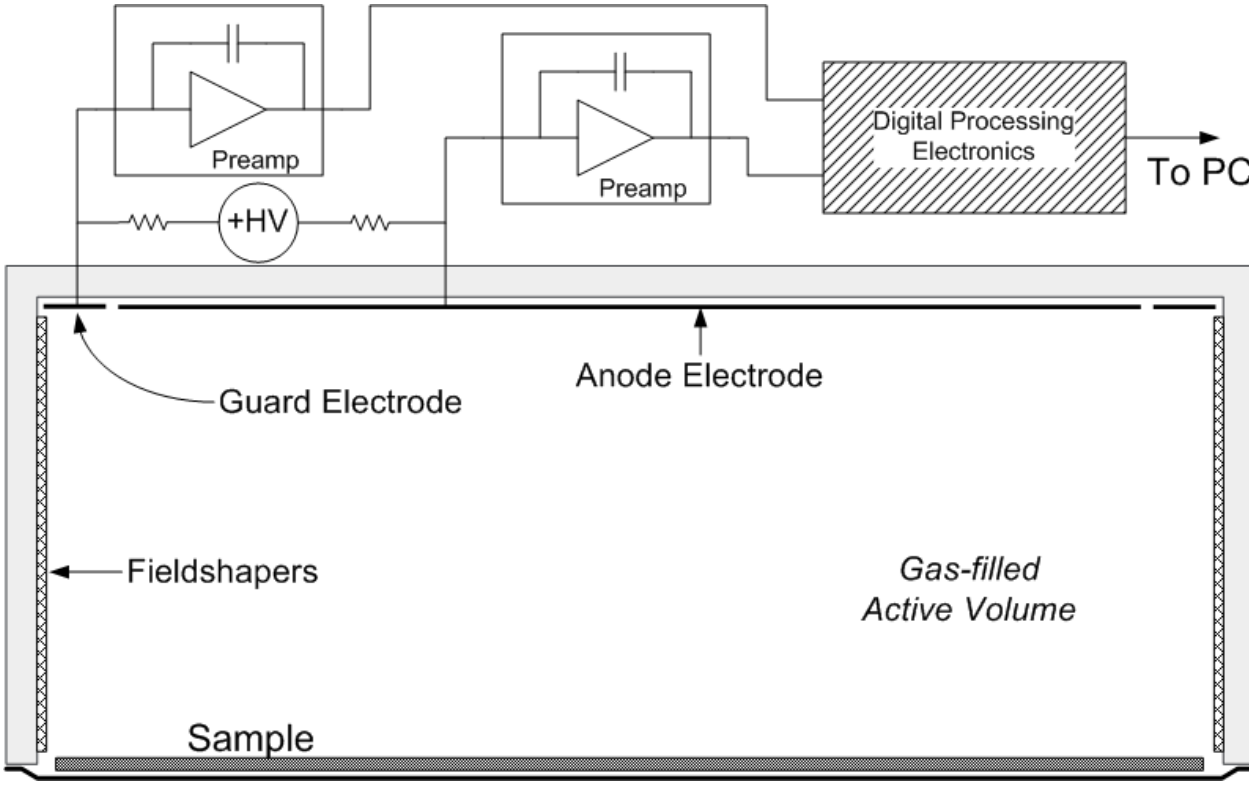


Figure II-1: Schematic overview of the UltraLo-1800.

reject all pulses except those from alpha particles emanating from the sample. This method allows the UltraLo-1800 to approach “zero background” measurements.

The following sections will examine these processes in detail: how the signals are induced, what the location-dependent characteristic shapes are, and how the pulse shapes are analyzed. Using this information, we will then also examine two related topics: what the sources of residual background are and when they need to be considered; and how to tell when the counter is not working properly and troubleshooting is required. Finally, we will review counting statistics as they pertain to UltraLo-1800's ability to provide estimates of the accuracy of its reported measurements.

Before moving on, we would like to re-emphasize the extremely strong correlation between output pulse shape and point of alpha particle emanation within the counter. In particular, this correlation leads to a shorthand verbal notation wherein we regularly refer to “a pulse resulting from an alpha particle (or ‘alpha’ for short) emanating from the sample” as a “**sample pulse**”, thereby contrasting it with “**ceiling pulses**” and “**sidewall pulses**”, whose initiating alphas emanated from the electrodes and sidewall, respectively. To avoid confusion, pulses in the anode and guard processing channels will be referred to as “anode” and “guard” pulses.

2. Electrostatic Description of the UltraLo-1800

To understand how the UltraLo-1800 works we start with a description of its active volume. As shown in Figure II-2, the active volume is set up as two parallel conductive plates separated by distance **D**. The top plate, called the **electrode,** is held at positive voltage (denoted **V** throughout), which is typically 1000 V. The bottom plate, called the **sample tray**, is held at ground potential and holds the sample to be measured. This arrangement produces an **electric field** (**E**) between the plates that has the value **V/D**. The volume between the plates is filled with a high-purity **counting gas**, in this case argon. Finally, the sides of the chamber, called the **sidewalls**, hold the **fieldshapers**, which are PCBs containing strips of copper separated by resistors that keep the electric field lines parallel throughout the volume.

Suppose a radioactive isotope on the sample tray decays, emitting an alpha particle in a random direction. In Figure II-2 it leaves the atom and is stopped in the gas after traveling some distance. This distance is called its **range** and is a function of both the alpha particle's energy and the specific gas species. As the alpha particle travels through the gas it loses energy by ionizing the gas molecules, producing a **track** of ion-electron pairs. The range and number of pairs (**N**) created in the gas increase with energy of the alpha particle. Being charged, these ions and electrons drift in the applied electric field, the electrons toward positive voltage on the electrode, the ions toward the tray. Each drifts with a velocity equal to its **mobility** (**μ**) in the gas times the electric field, or: $v_e = E \cdot \mu_e = V \cdot \mu_e / D$ (where the subscript "e" indicates "electron", and "i" would indicate "ion"). The mobility of electrons is thousands of times higher than that of ions, thus they drift to the electrode faster than the ions drift to the tray. How long does this take? If the electron is freed a distance **d** away from the electrode (as in Figure II-2), its drift time is $\mathbf{d/v_e}$ seconds, or $t_e = d \cdot D/V \cdot \mu_e$. When **d** is the height of the entire chamber, **D**=15cm, and **V**=1000V, then $\mathbf{t_e}$ is found to be approximately 70 μs in argon.

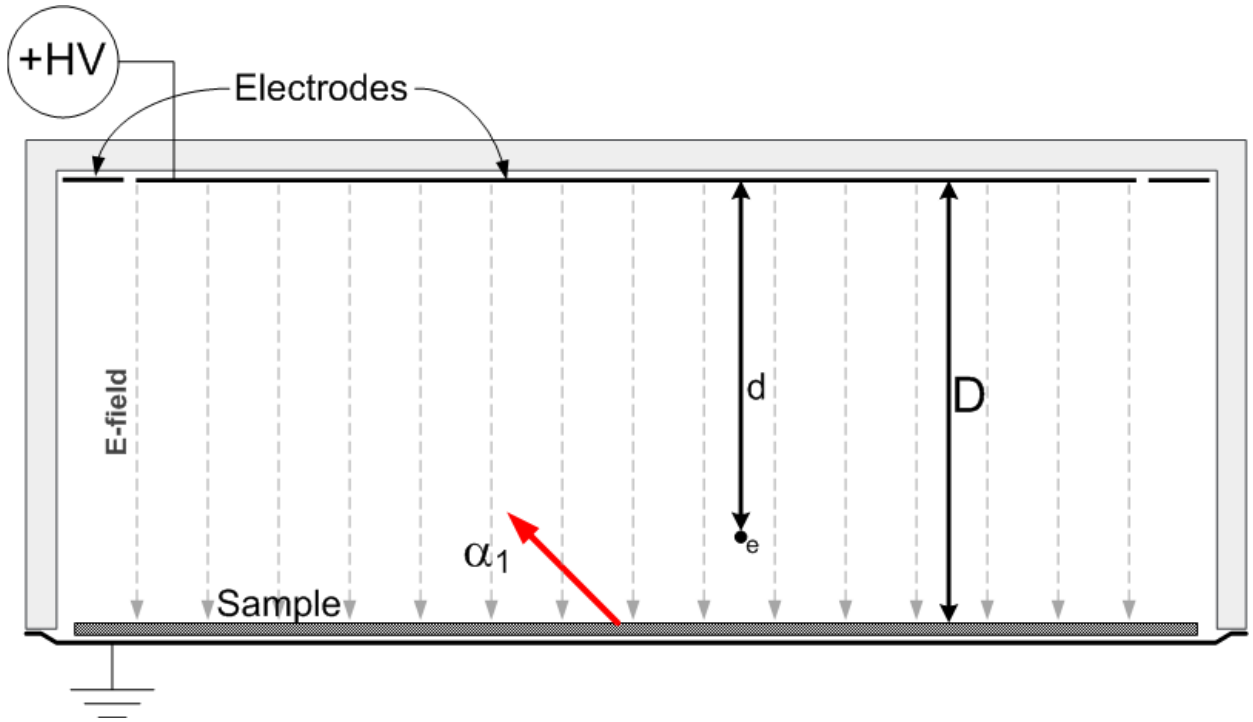


Figure II-2: Schematic overview of the important parts of the UltraLo-1800's active volume.

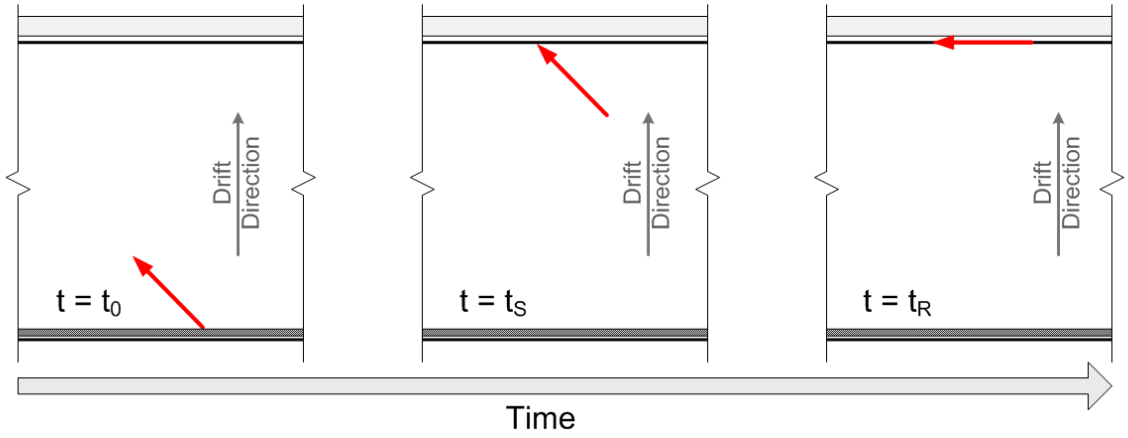


Figure II-3: The location of the electron track at the 3 important times.

All of the electrons in the track drift at the same velocity, so the initial geometry is preserved from the moment it is created ($\mathbf{t_0}$) until the first electron reaches the electrode ($\mathbf{t_S}$), as shown in Figure II-3. (There is some diffusion of electrons out from the track, but for our purposes this effect is negligible). As the track continues to drift, the electrode absorbs the electrons as they arrive, until they're all absorbed ($\mathbf{t_R}$). The time between $\mathbf{t_0}$ and $\mathbf{t_R}$ is called the **risetime**.

3. Signal Generation

As an electron moves toward the electrode it **induces** a current in the attached electronics. This may be understood through Gauss's Law, which states that the net electric flux through any closed surface is proportional to the enclosed electric charge. Because the electrode is a conductor it does not support internal electric fields, all external fields must terminate at its surface, which implies a net flux and, by Gauss's Law, the presence of charge on its surface. Further, any changes in the flux imply a change in the charge present on the surface and therefore imply current in the circuitry connected to the electrode that is proportional to the rate change of flux. This means that as the electron drifts toward the electrode it induces a current in the attached electronics (this is also known as the Shockley-Ramo theorem). This induction only happens while the electron is traveling; once it reaches the electrode its electric field disappears, the changing flux goes to zero, and therefore the induced current goes to zero.

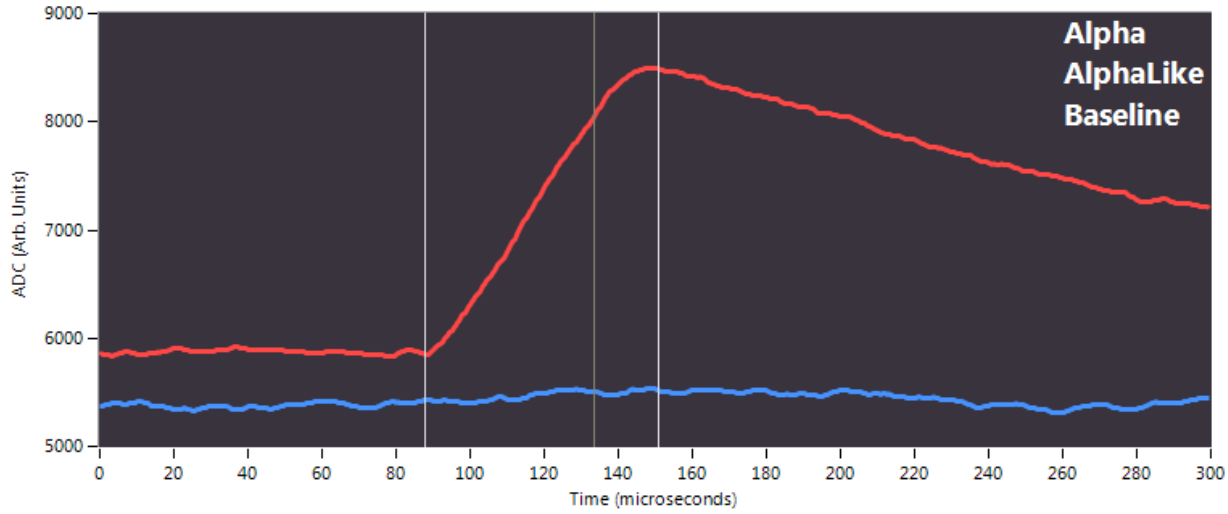


Figure II-4: Example of an alpha pulse. The anode is in red, the guard is in blue. The three lines are the three important times, from left to right t_0, t_S, and t_R. Note the rounding between t_S and t_R.

In the UltraLo-1800, tracks consist of hundreds of thousands of electrons, how do many electrons drifting at once behave? In that case the total observed current is the sum of the individually induced currents. If the track isn't parallel with the electrode, (and in general it won't be), some electrons in the track will induce current for longer than others, and once the track begins to hit the electrode (at $\mathbf{t_S}$) the rate of induction slows. The rate at which induction slows will be proportional to the angle of the track relative to the electrode; the further from parallel the longer it will take to slow. This slowing shows up as a **rounding** of the pulse from $\mathbf{t_S}$ to $\mathbf{t_R}$, as can be seen in Figure II-4.

What do these induced signals look like? In the UltraLo-1800 the electrode is connected to a charge-sensitive preamplifier that integrates the current. The preamplifier outputs a signal (in volts) that is proportional to the total current induced. As discussed above, for a track originating on the **sample** (α_1 in Figure II-5) there are two distinct regions in time: one from $\mathbf{t_0}$ until $\mathbf{t_s}$ where the electrons drift unchanged, and another from $\mathbf{t_s}$ until $\mathbf{t_R}$ where the electrons are disappearing linearly in time. The resultant integrated signal $\mathbf{S_s(t)}$ is thus linear until $\mathbf{t_s}$ and then parabolic until $\mathbf{t_R}$, the chamber's maximum transit time:

$$S_s(t) = \frac{Ne\mu_e V}{C_f D^2}(t - t_0)\ from\ t_0\ to\ t_s, \text{and}$$

$$S_s(t) = \frac{Ne\mu_e V}{C_f D^2}\left(t - \frac{(t - t_s)^2}{2(t_R - t_s)}\right)\ from\ t_s\ to\ t_R,$$

where $\mathbf{C_f}$ is the detector capacitance, **e** is the charge of an electron, and:

$$t_s = \frac{d_s D}{\mu_e V}, t_R = \frac{D^2}{\mu_e V}, and\ S_{sMAX} = \frac{Ne}{2C_f}\left(1 + \frac{d_s}{D}\right)$$

where $\mathbf{d_s}$ is the distance from the topmost electron of the track to the electrode (Figure II-5).

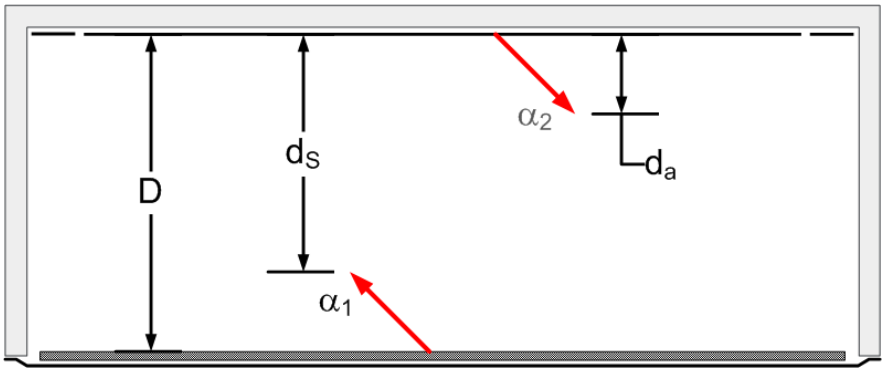


Figure II-5: Demonstration of important distances in the UltraLo-1800's active volume.

The resultant pulse is shown in Figure II-4. Note that $\mathbf{S_{sMAX}}$ scales with **N**, so that the final pulse amplitude is proportional to the energy of the alpha particle.

However, when a uniform charge track originates from the **electrode**, charge starts disappearing linearly in time immediately, so that the resultant signal $\mathbf{S_a(t)}$ is a parabola given by:

$$S_a(t) = \frac{Ne\mu_e V}{C_f D^2}\left(t - \frac{(t-t_0)^2}{2t_a}\right)$$

The risetime $\mathbf{t_a}$ and maximum amplitude $\mathbf{S_{aMAX}}$ are found to be:

$$t_a = \frac{Dd_a}{\mu_e V} \text{ and } S_{aMAX} = \frac{Ne}{2C_f}\frac{d_a}{D}$$

$\mathbf{d_a}$ being the track length normal to the electrode.

The important lesson to be drawn from this comparison of the two track types is that electrode pulses look different from sample pulses. Both the risetime and the maximum amplitude are much longer for sample pulses. Because the ratio of electrode to sample risetimes ($\mathbf{t_a/t_R}$) is $\mathbf{d_a/D}$, if the sample chamber is made several times the maximum range of an alpha particle, then the risetimes of the two cases will always be separated. The UltraLo-1800 is designed so this ratio will be about 1/3 for a 5 MeV alpha particle emitted perpendicular to the anode. Similarly, the ratio of maximum amplitudes ($\mathbf{S_{aMAX}/S_{SMAX}}$) for two identical alpha decays is $d_a/(D+d_s)$. This ratio is dependent on the angle of emission relative to the anode, but it will always be greater than or equal to the ratio between risetimes. Since **D** has already been chosen to exaggerate the difference in risetimes, the difference in amplitudes is exaggerated as well. Being able to differentiate pulses based on their risetime and amplitude is a key feature of the UltraLo-1800.

4. Necessary Assumptions

There are several assumptions that we must make in order for our model to accurately describe the physical counting system:

The first is that the electron drift speed is both uniform and known. Because electron mobility changes with the type of counting gas, so does the drift speed. Further, it can also change by significant amounts if the counting gas isn't pure (e.g. concentrations of water of only 100 ppm can decrease risetimes significantly). By selecting the correct operating gas in CounterMeasure and purging for adequate amounts of time these assumptions should always be met (unless the material being counted is itself a source of water vapor, see **No Alphas**).

We also assume that the charges are free to drift all the way across the active volume. This assumption can break down if there are significant amounts of oxygen in the active volume, since O_2 has a high electron affinity. As above, adequate purging also makes this condition easy to satisfy.

A third assumption is that the electric field is uniform, which is guaranteed by the design of our active volume, but can be perturbed if, for example, materials with significant height or very high resistivity are placed on the sample tray (see **Counting Various Sample Types**).

Finally, when we report energies we assume that all alpha energy is expended in the gas. If the alpha isn't emitted from the sample's surface (**surface emission**) and passes through some amount of material before entering the active volume, then its energy will be reduced by some unknown amount. Because it's impossible to know how much material an alpha passed through we cannot correct for this. However, bulk sources (as these kinds of samples are called) show certain behaviors that are understood, see **Bulk Sources** for more information.

B. Secondary Veto Channel

1. Rejection

The second key design feature that allows the UltraLo-1800 to be "zero-background" is its veto, or guard electrode. The electrodes are arranged as shown in Figure II-2 and are read out simultaneously, with the interior, active portion called the **anode**, and the exterior portion called the **guard**. As can be seen from Figure II-6, tracks originating on the counter sidewalls or on the tray outside the sample region will induce signals on the guard and can be rejected. When combined with the risetime discrimination discussed earlier, we are capable of rejecting events that originate on any surface other than the sample.

2. Counting Efficiency

Because the direction of emission of an alpha is random, some events that originate near the boundary of the electrode, but still on the sample, may be rejected because part of their track crosses the boundary (see α_4 in Figure II-6). The end result is that the UltraLo-1800 has a **counting efficiency** that is less than 100%, and decreases with increasing energy (higher-energy alphas have longer track length, and longer track lengths are more likely to cross the boundary). We have calculated this efficiency loss both directly and with Monte Carlo simulations, and take it into account when calculating an emissivity with CounterMeasure. For a 6 MeV alpha particle the overall efficiency in the 707 cm^2 configuration is about 85%, and in the 1800 cm^2 configuration it is about 90%. When we report emissivities they take this correction into account, see **Emissivity Value** for more details. For a table showing the correction values, see **Counter Efficiency**.

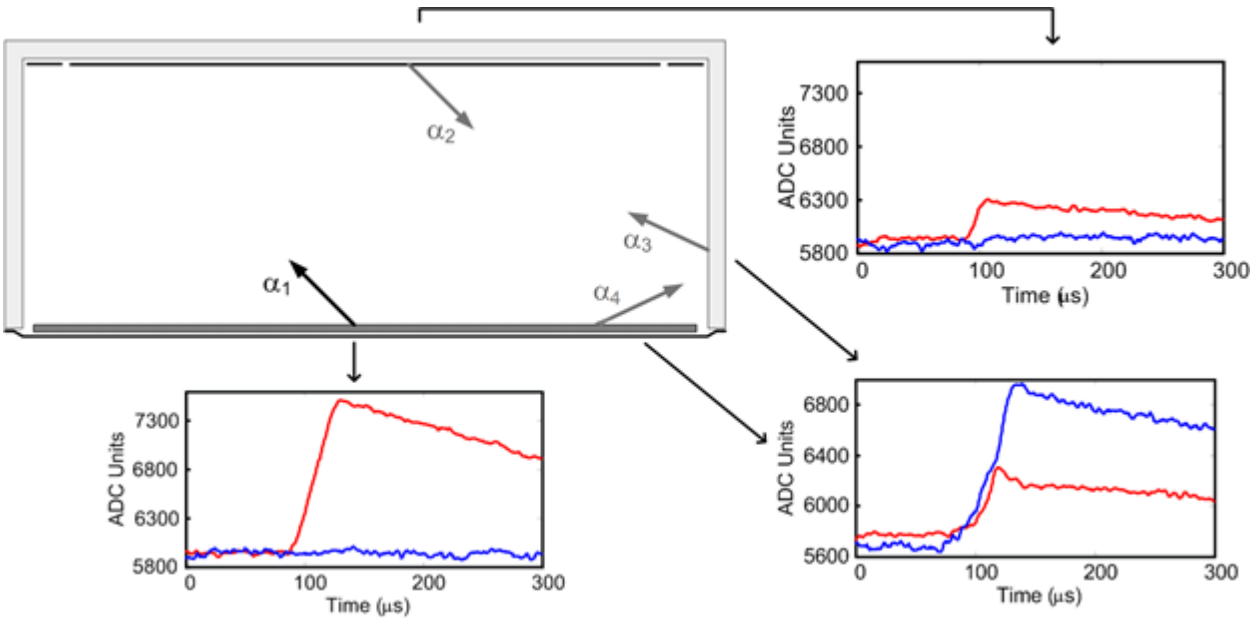


Figure II-6: Alphas originating from various locations in the counter and their resulting pulses. α_1 shows a sample alpha, α_2 shows a ceiling emission, and α_3 shows a sidewall emission, and α_4 shows a sample alpha that travels under the guard. The anode pulse is shown in red, the guard in blue.

3. Induction

The final phenomenon resulting from the split electrode is what we call **charge induction** (also called Ramo induction). A pulse with significant charge induction is shown in Figure II-7. When electrons drift near the boundary between the two electrodes, they will induce some charge on both electrodes, even if they're entirely located under only one. But as they move closer to the electrodes, that induction will diminish and eventually disappear, except on the electrode where the electrons are finally collected. This phenomenon is a result of the physics discussed in **Signal Generation**. When the charges are far away the flux they cause on the surface of the electrodes is spread over a wide area. As they drift closer this area decreases. If this area is initially shared by both electrodes, as it diminishes the rate change in flux (and, by the Shockley-Ramo theorem, the induced charge) will itself change, increasing on one electrode and decreasing on the other. The result is a pulse on the collecting electrode that has the same final height as it would if it originated far from the boundary, but with significantly more curvature in its rising edge, while the signal on the other channel will be at the same level at the beginning and the end but with a significant bump that falls directly under the curved portion of the other trace. Our algorithm looks for these signatures, and when we find them, we perform **add-back**, a specialized procedure designed to provide a more accurate estimation of risetime and energy, and thus a more accurate classification of the pulse.

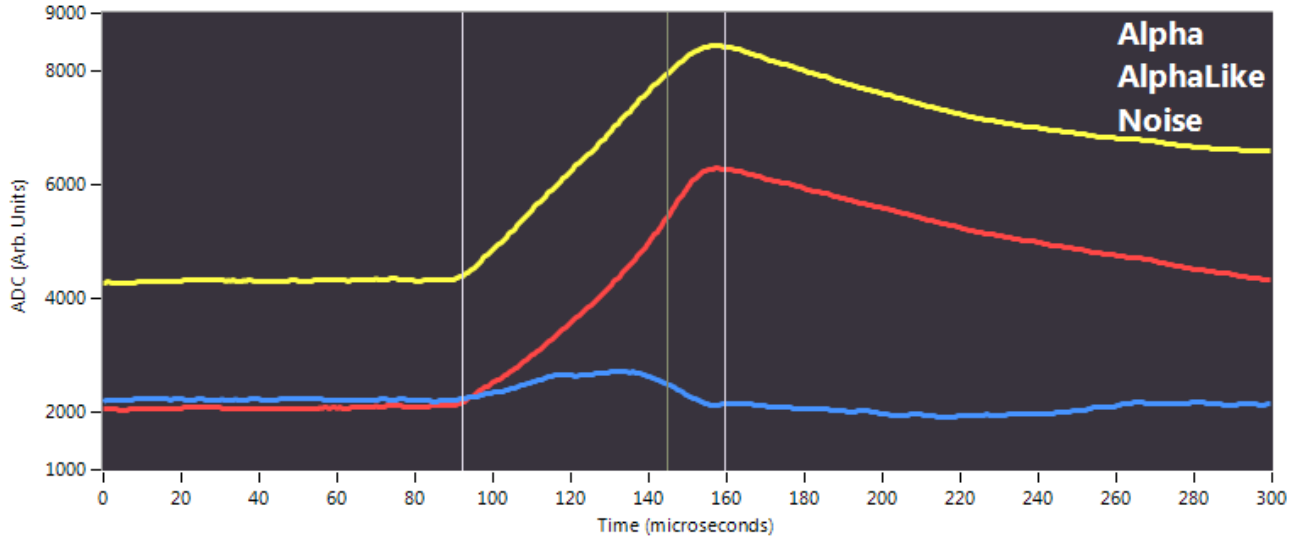


Figure II-7: Pulse with significant induction. Note the negative curvature on the anode (red) and the hump on the guard (blue). The yellow line is the "add-back" trace, discussed in the text.

C. Comparison to Gas Proportional Counters

As previously mentioned, the UltraLo-1800 is an ionization counter and most other low-rate, large-area alpha counters are proportional counters. There are some important differences between the two, and if you're familiar with proportional counters some, but not all, of that familiarity will be able to transfer over.

First we'll look at similarities. Both types of counters are filled with inert gas, both use the electron-ion pairs formed by alpha particles, both use electrodes to collect the signal, and the pulse processing equipment is largely similar.

The main difference is the electric field in the counter. For ionization counters the field's value stays fairly low and is uniform (the UltraLo-1800's field is around 66 V/cm) while gas proportional counters have fields high enough to create **electron avalanches**. An electron avalanche occurs when drifting electrons accelerate to energies high enough to create electron-ion pairs themselves. The created electrons can then accelerate and create more pairs, causing an "avalanche" of electrons. In proportional counters this process is called **gas multiplication**. To create avalanches proportional counters typically have an anode composed of thin wires, this creates a region of very high electric field close to the wire, which is called the **multiplication region**.

These small changes have large practical consequences. The most immediately obvious is that the proportional counter has a large internal gain, and so the resulting signals are much larger and easier to process. This means less electronic noise and fewer design constraints on detector parts such as preamplifiers. The higher noise and more difficult design for ionization counters is why proportional counters were long the favored device for low-rate, large-area counting.

However, the tradeoff for this internal gain is that proportional counters lose any information about where the pulse originated. Pulses from the counting tray look the same as those from the sidewalls, the ceiling, even the electrode wires themselves. This is because the vast majority of the signal comes from the time between the first electrons of a track entering the multiplication region and the final multiplication ending. The duration of that signal is only dependent on the orientation of the track relative to the anode wires, and not on where the track originated in the detector. (See Figure II-8 for a

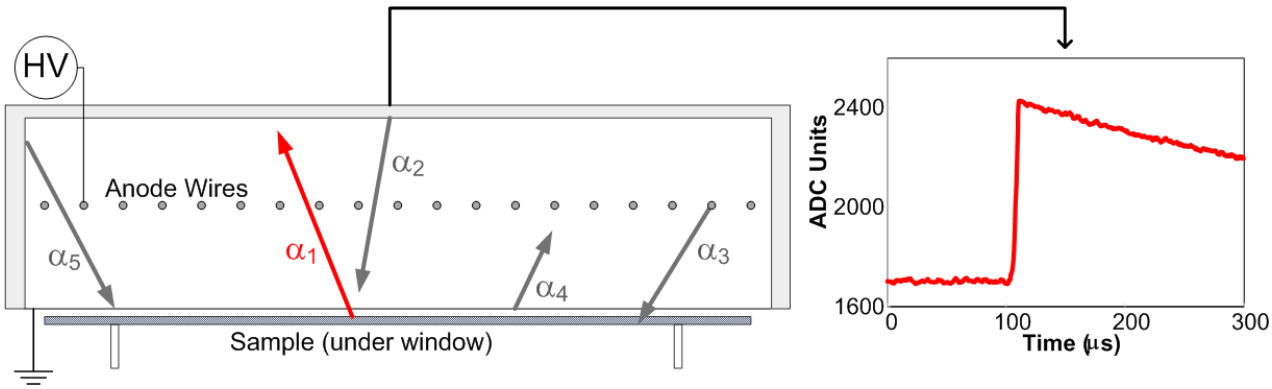


Figure II-8: Events and the resulting pulse from a proportional counter. All events result in the same pulse shape.

graphical depiction.) This means that pulses produced by a proportional counter contain no information about the pulses' point of origin in the detector, while an ionization counter's pulses do. As discussed earlier, knowing where pulses originate enables you to reject those which do not originate from the sample. This fact allows the UltraLo-1800 to have a significantly lower intrinsic background than a proportional counter made of similar materials.

In short, the important difference between the gas proportional counter and the ionization counter in this context is that the ionization counter has poorer signal-to-noise, but saves information about where pulses originated in the detector.

D. Remaining Background Sources in the UltraLo-1800

While the UltraLo-1800 is capable of filtering out pulses originating from its various internal surfaces (and is in that sense "zero-background") there still remain several known sources of rarer events that produce traces that our software classifies as sample alphas but that do not originate from the sample. Thus these sources contribute to a background rate that we presently estimate to be about 0.0005 counts/hr/cm^2 in the UltraLo-1800 (for a counter at sea level with no significant overhead shielding). The following background sources are under active R&D at XIA, see our website for more details.

1. Cosmogenics

Historically, ionization counters were most commonly used for measuring fluxes of cosmic radiation, and we've discovered that the UltraLo-1800 still works for that purpose. Early on in the development of the detector we observed pulses that didn't look quite like alphas. While alpha pulses will have some rounding at their peak (due to the absorption of the electrons into the electrode), the rounding observed on these pulses was much more significant (see Figure II-9). We created a new class of pulse (the "**round**") in order to separate them out while we pursued their origins. From early on we suspected they were caused by cosmic rays, but proving it experimentally was difficult. The reason we suspected cosmic rays is that in order to observe a very rounded peak the ionization track would need to be very long, but in order to deposit energy equivalent to a 1-5 MeV alpha particle it would have to have a fairly high dE/dx. Alpha tracks are too short and dense, and beta and gamma rays are far too weak. This leaves some kind of cosmic ray, most likely a light baryon such as a proton.

A recent experiment conducted by XIA [talk available online] showed a strong dependence between elevation/depth and observed round rate. These findings clearly indicated that rounds are indeed caused by cosmogenics.

While we can identify and filter out cosmogenic events with some efficiency a few will still pass through our analysis and show up as alphas, particularly at low alpha energies where our signal-to-noise

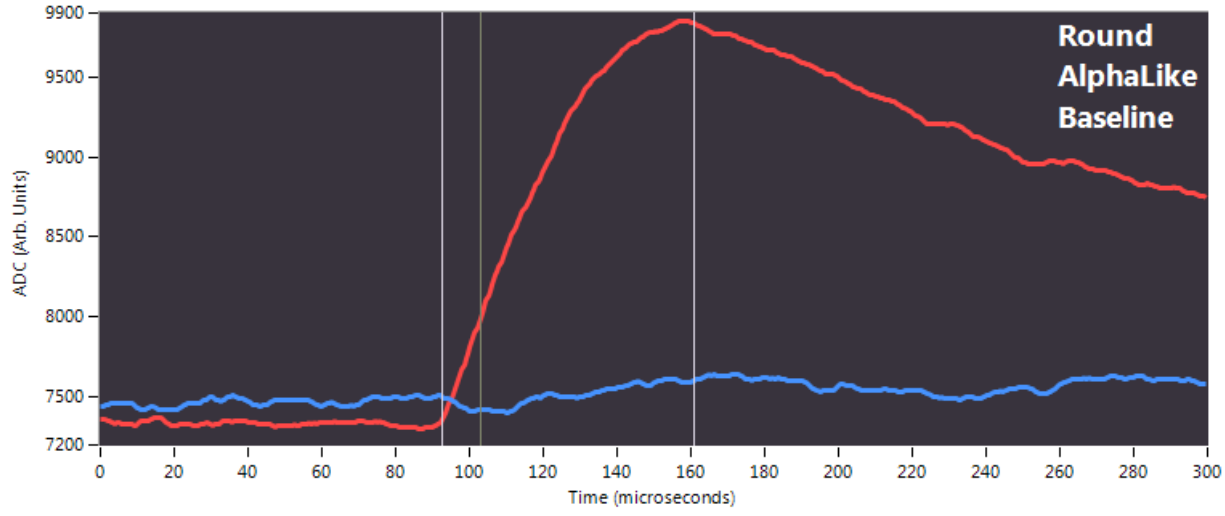


Figure II-9: A "Round" pulse. Note the extremely large time between t_S and t_R (second and third lines, respectively). The anode is shown in red, the guard in blue.

ratio is worse. It is difficult to precisely measure this probability because of the inherent difficulty in disentangling cosmogenics from true low-energy alphas. This difficulty is compounded by the fact that the magnitude of the effect can vary greatly between different locations, with altitude, shielding provided by building materials, and other factors contributing. Additionally the different electrode configurations will see different rates. This is because the 707 cm^2 configuration has a much smaller solid angle that a cosmic ray could pass through without leaving energy on the guard compared to the 1800 cm^2 configuration. The difference is greater than the difference in area alone, and therefore the 707 cm^2 configuration sees fewer rounds. We can say that at XIA (which is at about sea level with no special shielding) we see approximately 8 rounds per hour in the 1800 cm^2 configuration, and that only a small percentage of those can make it through our analysis (about 5%), which leads to a background rate of about 0.0002 counts/hr/cm^2. Additionally, virtually all of these are low-amplitude events, below 3.5 MeV. There are no common isotopes that emit alpha particles of that energy, so pulses in that range can only be produced by bulk decays or rounds. Therefore this background can be virtually eliminated by providing a stringent energy cut at around 3.5 MeV if one is only interested in surface activity.

Finally, it's important to note that a cosmogenic background will be present in any gas-filled counter, including proportional counters. And, as noted earlier, in proportional counters they cannot be identified by shape as all pulses have the same shape.

2. Radon

The other source of background in the UltraLo-1800 is radon gas. Radon is a noble gas, and as such is nonreactive and capable of diffusing some distance through materials (especially plastics). It's also radioactive (in fact, it's the second-leading cause of lung cancer in the US). These two properties combine to make it a pernicious source of background in any counting experiments. There are two common isotopes of radon, ^{220}Rn (also called "**thoron**" because it comes from the ^{232}Th chain) and ^{222}Rn (sometimes the word "radon" is used solely in reference to this isotope, but as this is potentially confusing in this manual "radon" will always mean the element with no specific isotope implied). The decay chains of both are shown in Figure II-10. The two chains have very distinct alpha-decay energies, and their spectra in equilibrium are shown in Figure II-11. Outside of equilibrium one or more of the peaks may be missing, depending on conditions. A spectrum with a peak in any of those locations is generally indicative of some kind of radon contamination on the sample.

In the UltraLo-1800 radon can show up in two different ways: in the "ongoing exposure" case, by being continuously present in the counting gas itself; or in the "terminated exposure case" by decaying

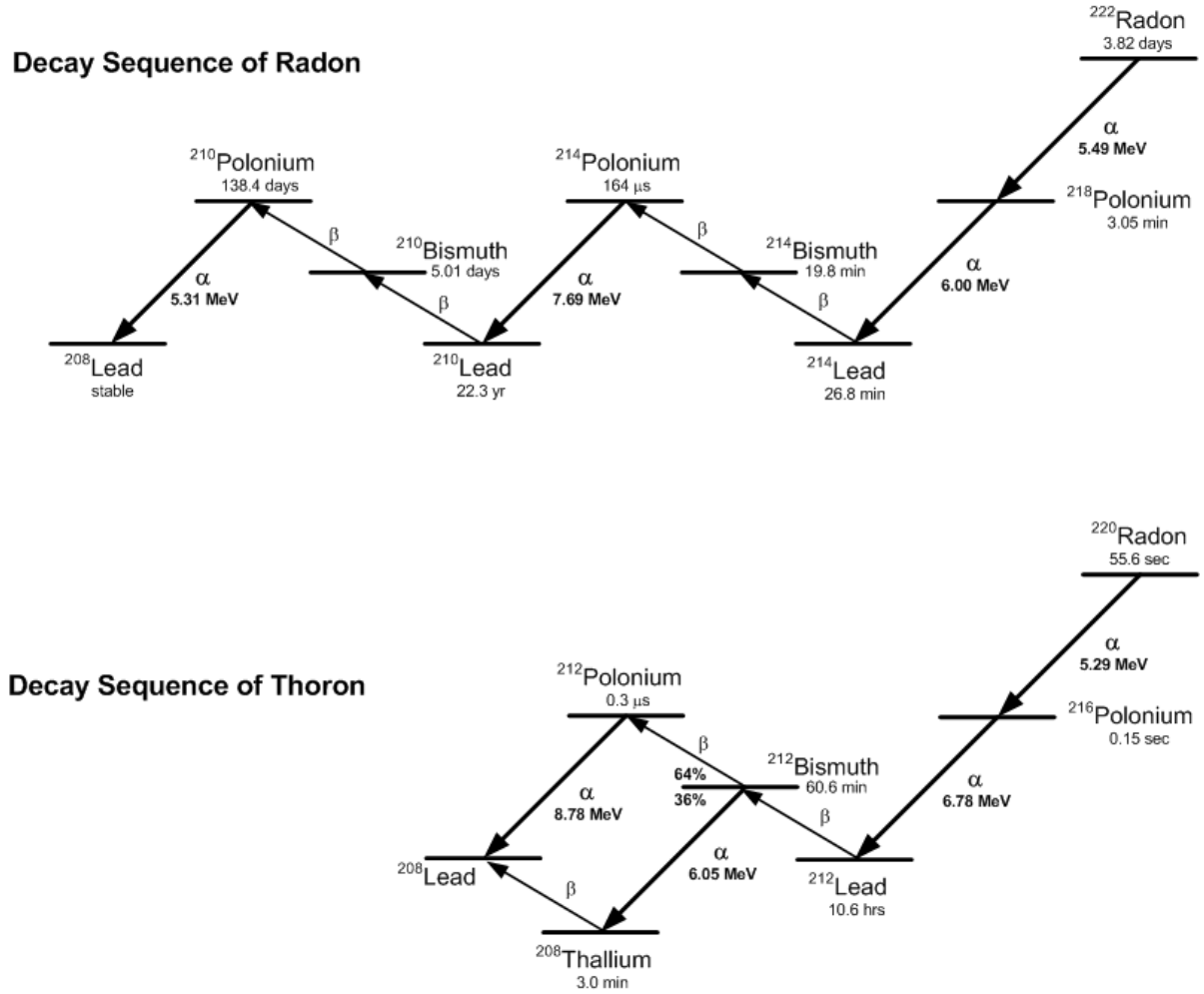


Figure II-10: Decays series of ^{222}Rn (top) and ^{220}Rn (bottom).

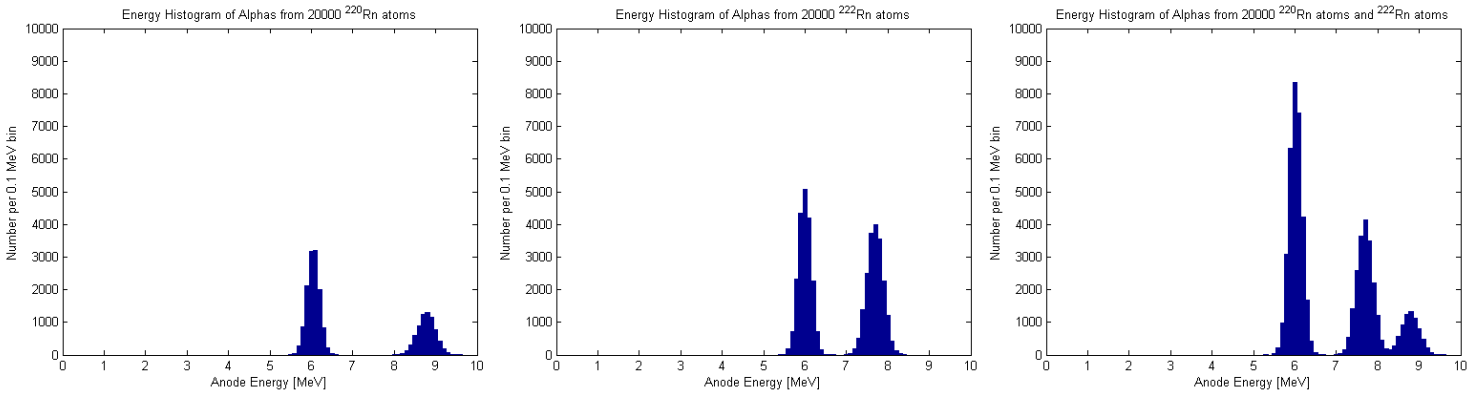

Energy Histogram of Alphas from 20000 220Rn atoms
Energy Histogram of Alphas from 20000 222Rn atoms
Energy Histogram of Alphas from 20000 220Rn atoms and 222Rn atoms
Number per 0.1 MeV bin
Anode Energy [MeV]

Figure II-11: Simulated spectra from radon as they appear in the UltraLo-1800 based on the terminated exposure case. Given the purge time and measurement windows, some peaks aren't apparent. ^{220}Rn (left) has small peaks at 6 and 8.6 MeV. These are small because of the split decay of ^{212}Bi. The other decays in the chain are too fast to see through a purge. ^{222}Rn (middle) has similarly-sized peaks at 6 and 7.7 MeV. As before, some peaks are not visible because of the purge, but additionally ^{210}Po is not shown because of the long half-life of ^{210}Pb. A peak at 5 MeV is a giveaway for ^{210}Pb contamination in a sample, but that is a separate problem. Finally, there's a combined spectrum (right).

near a sample and contaminating it with its daughter isotopes prior to insertion of the sample into the Ultra-Lo, which "terminates" the exposure. The two cases can be distinguished with relative ease, since all of radon's daughters are either short-lived or very long-lived. If the exposure was terminated prior to inserting the sample in the counter (case 2) there will be a distinctive drop in the emissivity through the run (see Figure II-12). In contrast, in the ongoing exposure case no such drop will occur. Exposure prior to measurement can be easily dealt with by simply waiting for the isotopes to decay (which takes a few hours for ^{222}Rn and several days for ^{220}Rn). However, the problem of radon in the active volume has no easy fix.

How does radon get into the active volume? There are many possible sources of exposure, including the reservoir of counting gas, the tubing leading the gas into the counter, diffusion in through the counter walls, or generation from minute ^{232}Th/^{238}U contamination in the materials of the counter.

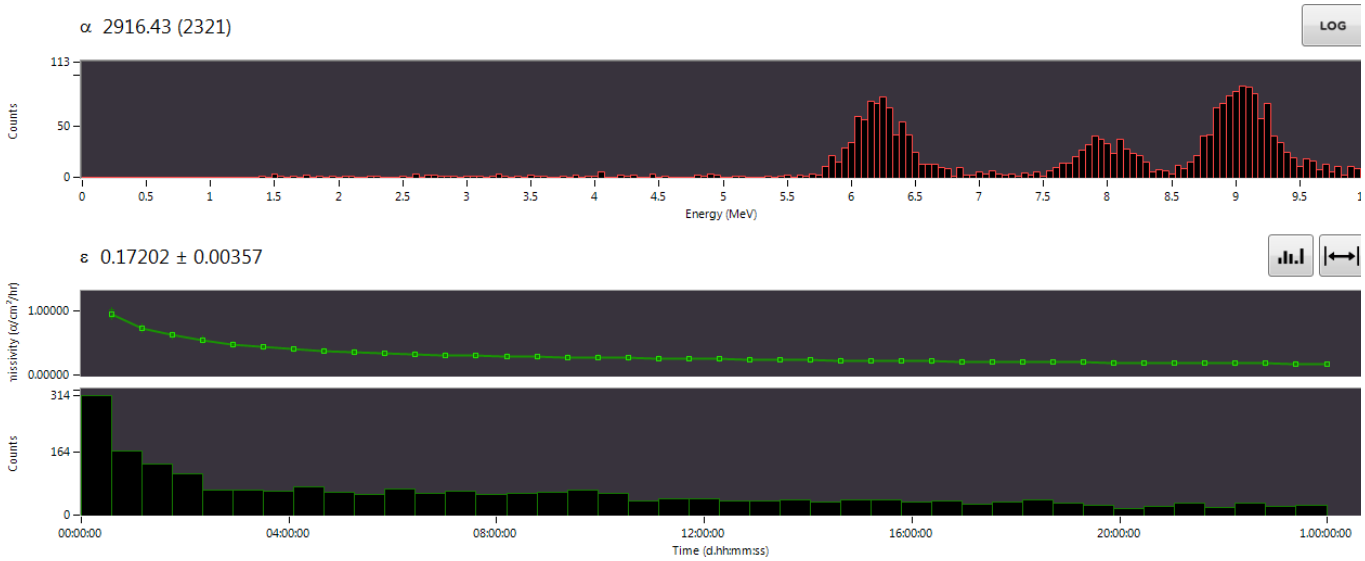


Figure II-12: A run with significant terminated radon exposure. Note the similarities to the simulated combined spectrum above.

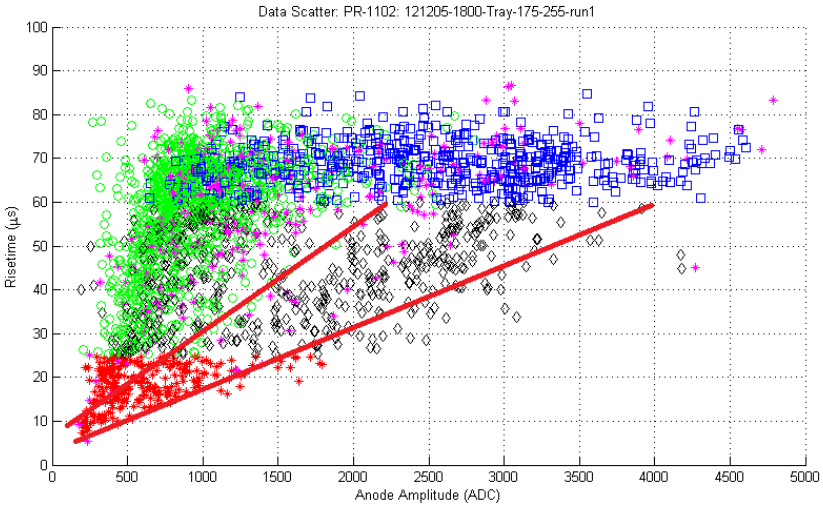


Figure II-13: The "band" of midairs (black), starting from ceilings (red) and going toward alphas (blue). There are a number of midairs outside this band that are caused by other phenomena, most are likely misclassified cosmogenics (green). At low energy the timing parameters separating rounds and midairs become difficult to determine accurately.

Radon in the counting gas gives rise to a very specific signal. First, the decay of the radon atom itself occurs anywhere within the volume with equal probability. Because of the geometry of the counter, most of the resulting tracks will have a risetime shorter than a typical alpha and longer than a typical ceiling event. We call these events "**mid-airs**", and they form a band of increasing energy and risetime that spans between events that occur just off of the electrodes to events that occur right next to the tray (see Figure II-13). Some of these radon decays will have similar risetimes as alphas and thus be classified as alphas (after all, they are alpha decays occurring near the sample tray). We can estimate this rate, and it's about 0.00025 alphas/cm^2/hr in the Full configuration. The innate background will not change over time or between different environments if the counter is set up and maintained correctly. (Counters have been run in underground labs with external radon activities of over 500 Bq/m^3 with no increase in midairs.) If you see more activity than around 5 midairs per hour, see **Excess Events**.

Finally, because thoron has a precise decay chain and every alpha decay has a specific energy, any signal from thoron will create a specific spectrum. For an example of how this looks in the UltraLo-1800, see Figure II-12. The rate of thoron decay in the chamber is so low that this spectrum takes many days to appear and will only be noticeable with very low-count samples. However, familiarity with this spectrum (and the spectrum of ^{222}Rn, also shown in Figure II-11) could help diagnose other forms of radon contamination, such as emission from a sample or terminated contamination.

3. Undersized samples

The design of the UltraLo-1800 assumes that the entirety of the area underneath the anode is occupied by the sample. If that area isn't fully occupied, the exposed tray's activity will be equivalent to a background. In this case all of the normal background subtraction methods can be used. If you're unfamiliar, the idea behind background subtraction is to subtract the number of counts you'd expect the tray to emit, on average, from the total observed counts, leaving behind only counts from the sample. The equation for background subtraction that's pertinent to the UltraLo-1800 is:

$$\varepsilon_{BS} = \frac{\varepsilon_T A_T - \varepsilon_B \left(1 - {}^{A_S}/_{A_T}\right)}{A_S}$$

And the error is:

$$\sigma_{BS} = \frac{1}{A_S}\sqrt{(\sigma_T A_T)^2 + \left(\sigma_B \left(1 - {}^{A_S}/_{A_T}\right)\right)^2}$$

Where ε_T is the measured emissivity that is being corrected, ε_B is the background emissivity, A_S is the area of the sample, A_T is the total area (either 707 or 1800 cm^2), and σ is the error in a given emissivity measurement. Taking a background immediately before or after the sample measurement is best, and it should have as small an error as feasible to minimize the error in the background-subtracted emissivity.

4. When backgrounds become important

Our best estimate of the total background in the UltraLo-1800, at sea level, is about 0.0005 alphas/cm^2/hr. As long as the emissivity of a sample is significantly above this number (say around 0.005 or higher) then the background can be safely ignored as it will only have a minor impact on the final results. But as sample emissivity gets lower the fact that these backgrounds exists becomes more important. At ultra-low emissivity values (below ~0.002) the background is a large contribution to the measured emissivity and its existence must be taken into account. Unfortunately, because the background will vary between individual counters and different locations (due to small differences in material construction, elevation, and overburden), we cannot provide an exact estimate of the background, and it will need to be inferred from the behavior of the counter over time.

There are some estimates we can make, however. Based on the counter geometry, for every 6 midairs there will be about 1 that gets classified as an alpha. The estimate for rounds is more difficult, but based on experiments with a previous generation of counter, for every 20 rounds there will be about 1 misclassified as an alpha. This means that if a two-day run in the 707 cm^2 configuration has 31 alphas, 42 midairs, and 100 rounds, we'd expect its true alpha count to be 31-42/6-100/20 = 19. This changes its emissivity from 0.00091 (ignoring the corrections due to **Counter Efficiency**) to 0.00056 alphas/cm^2/hr. Keep in mind that there is substantial uncertainty in these estimates, so this will increase the error significantly.

III. Sample Handling

A. Standard Good Practices

There are several practices that will help minimize contamination of your samples and ensure that your results are as accurate as possible. Most are straightforward prescriptions any lab can follow, a few require specialized equipment. The most important thing you can do to ensure cleanliness is to think about cleanliness.

- Keep samples covered whenever possible. This helps minimize radon contamination (see **Radon**)
- Only handle samples with clean instruments. Clean instruments are free from debris and are regularly washed (for recommended washing procedure, see **Cleaning Procedure**).
- Keep hands gloved at all times, even when not handling samples directly. Use only powder-free gloves. At XIA we use powder-free blue Nitrile examination gloves.
- Regularly clean instruments and tray surfaces, as well as anything else that comes into contact with samples.
- If available, store samples in glovebox or other purged container, particularly before counting. If a purged container is not available, a sealed or covered container is best.

B. Interactions Between Sample Handling and Results

In all but the cleanest of environments, more sample handling means more contamination. Because of this it's best to handle samples as little as possible. In addition, more exposure to atmospheric air will lead to more contamination with radon (as discussed below). For these reasons, it's incredibly important to handle samples as little as possible, store them in as clean of an environment as possible (either a purged box or a sealed container), and move them from their storage location into the counter as expeditiously as possible.

C. Radon

Radon and its effects on the UltraLo-1800 are discussed in depth in **Radon**. In terms of sample handling the most important thing to know about radon is that the contamination on a sample is proportional to the radon concentration in the environment around the sample and the size of the air column above it. While radon can diffuse through many materials, including most plastics, the actual range is quite small. This means that simple measures can prevent much contamination, and protecting samples from radon can be as simple as sealing them in a Ziploc bag. More extensive measures, such as chambers under constant N_2 purge, can be even more effective, but as long as the sample isn't exposed to high levels of radon for extended periods of time the contamination will be minimal. For a detailed treatment of this topic, see The Effects of Exposing Samples to Room Air.

D. Cleaning Procedure

There are two types of cleaning procedures we use at XIA while working with the UltraLo-1800, a quick and a thorough clean. Quick cleans are used when there's minor contamination of a sample or handling instrument, whereas thorough cleans are used for major contamination and for routine precautionary cleaning. All cleans should be done using lint-free clean wipes, which are very important (an example of lint-free wipes is here). If the wipes leave behind residue the cleaning procedure could be actively harmful, so using lint-free is essential.

1. Thorough

The thorough clean is designed to eliminate radioactivity on the sample. (Here "sample" refers to whatever is being cleaned, not necessarily something being measured in the UltraLo-1800.) The first step is a liberal rinse with Radiacwash, an anti-radioactivity cleaning formula from Biodex (available here). Radiacwash contains mild acids and will slightly etch some metals, including copper. After several moments remove the Radiacwash with distilled or deionized water, using enough to ensure that all of the Radiacwash has been swept away. Finally, rinse with alcohol (at XIA we use methanol for its exceptionally fast evaporation, but isopropanol will work as well). Note that this procedure can be done without wiping the sample at all, but wiping with clean wipes can help spread or remove the various liquids. However, if there is concern about keeping the surface of the sample pristine, using only the liquids will still provide effective cleaning. For information on the results of this cleaning, see The Effects of Exposing Samples to Room Air.

2. Quick

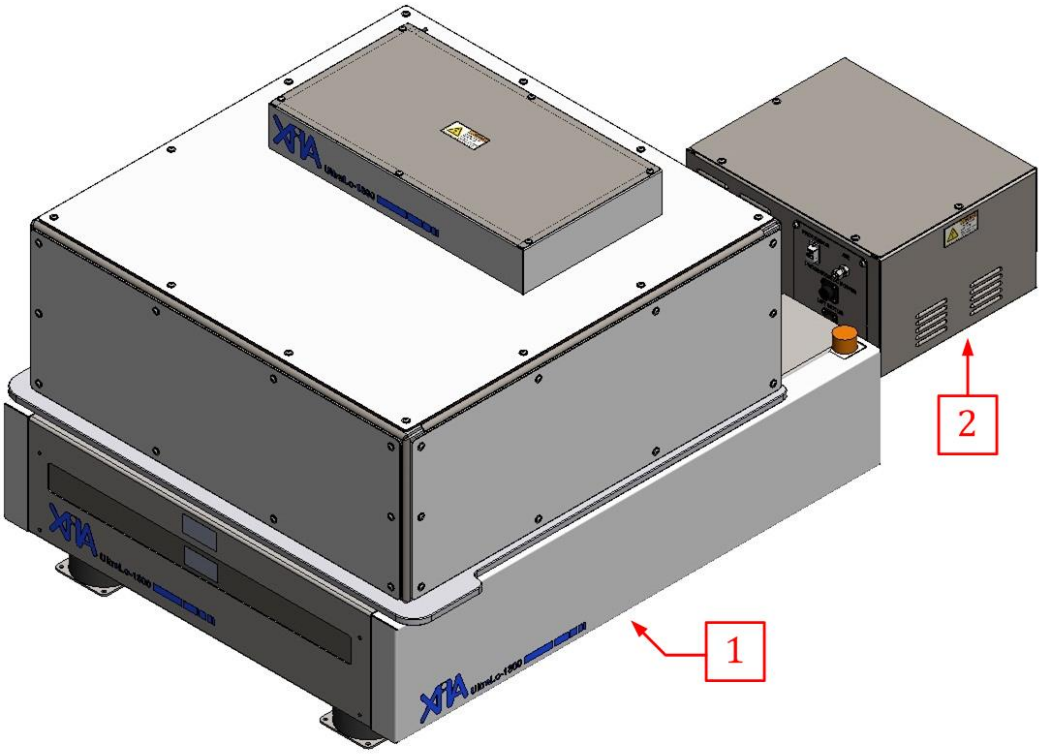
If a sample or instrument needs a simple cleaning then a rinse with alcohol and rubbing with a clean wipe is often sufficient. This quick wash should be used regularly on instruments (such as tweezers) to minimize cross contamination. In addition, the tray (or any covering) should be frequently washed (e.g., weekly) with this method.

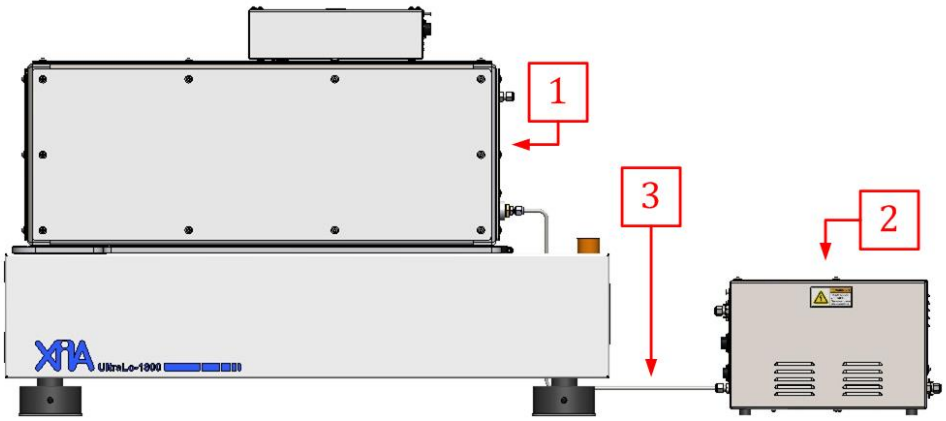
IV. System Overview

A. Components

1. Complete System

1. Counting Module: The main body of the UltraLo-1800.
2. Support Box: Houses several necessary components that are separated from the counter for noise reasons.
3. Rigid Gas Tube: Connects Support Box gas output to Counting Module gas input.
4. Control Laptop: Communicates with the UltraLo, takes and stores data (not shown).
5. 3/8” Hex Key: For opening the Counting Module (not shown).





2. Counting Module

- Side View (Panel Removed)
  1. Electronics box, houses the electronics that perform many of the communication and counting functions of the UltraLo. These include:
     - Processing electronics: Digitize the incoming signals, look for triggers, send data to the Control Laptop (not shown).
     - HV generation: Generates the High Voltage needed for electron drift (not shown).
     - Communications: Communicates both signals and device information (e.g. high voltage bias, moisture) values to the Control Laptop (not shown).
  2. Upper Chamber, contains:
     a. Preamplifiers: Analog amplification of the signals coming from the Active Volume.
     b. Moisture meter: Measures the moisture in the Active Volume in order to ensure a dry counting environment.
     c. Active Volume (ionization chamber). Includes:
        - Electrodes: The drifting electrons induce charge via the electrodes (not shown).
        - Fieldshapers: Ensure that the electric field is uniform (not shown).
  3. Lower chamber, introduces samples into the Active Volume. Primarily contains:
     - Tray/Door mechanism: Connects the motor to the tray and door, so that samples may be introduced and a gas seal created in a reliable manner (not shown).

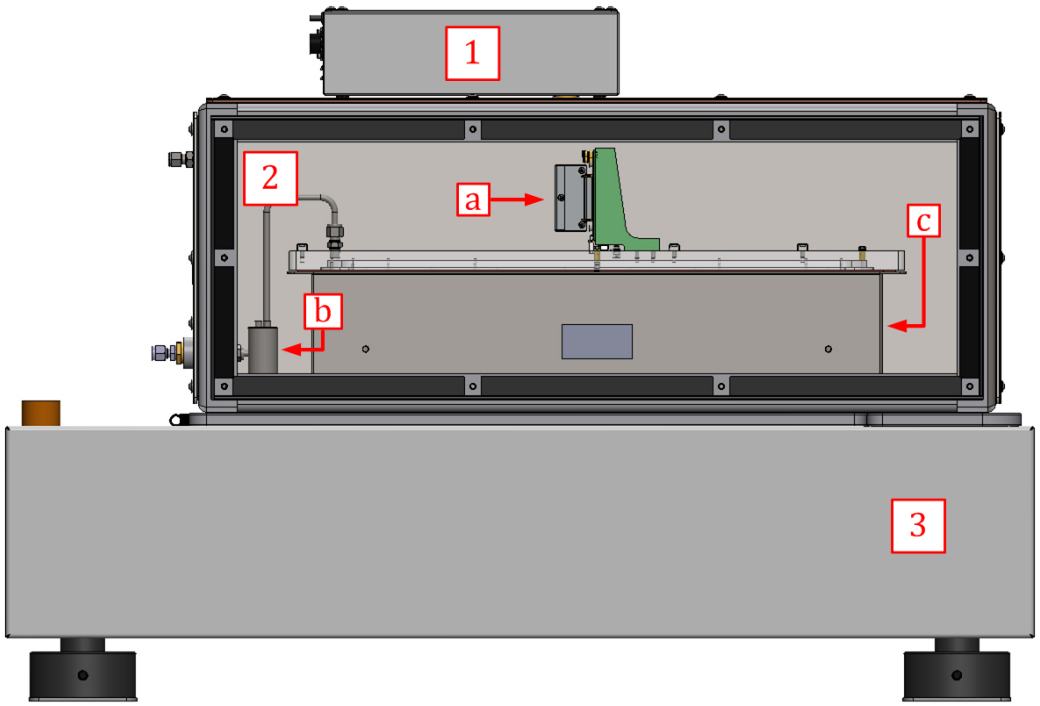


Figure IV-1: Side view of counting module with the panel removed.

- Rear View
  1. Air inlet: Purges the outer chamber with air in case of any argon leaks.
  2. Power connector: brings power to the electronics.
  3. USB cable opening.
  4. Gas inlet: Allows argon into the Active Volume.
  5. Gas outlet: Provides a controlled exit of argon from the Active Volume.
  6. Check valve: Provides overpressure exhaust relief.
  7. Pressure gauge: Allows reading the internal pressure to ensure that gas exit and the door seal are working as intended.
  8. Motor enclosure: Powers the tray mechanism.
- Front View
  9. Door: Forms seal to keep argon pure, allows samples to be introduced.
  10. Side fairings: Aesthetic coverings.
  11. Vibration isolating feet: Damp mechanical vibrations.

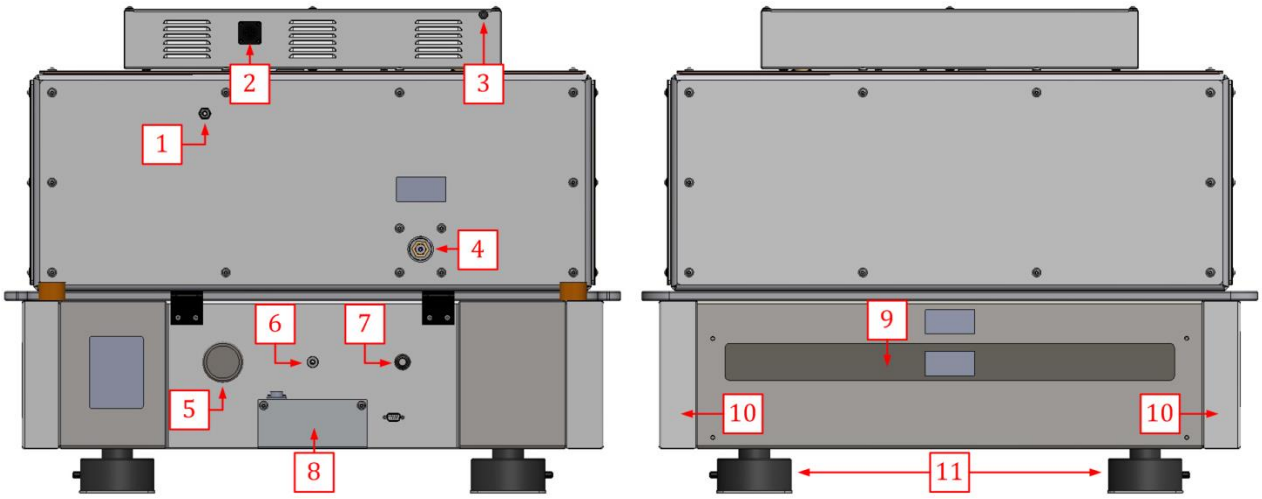


Figure IV-2: Right: rear view of counting module. Left: front view of counting module.

3. Support Box

- Rear View
  1. Argon gas input
  2. USB to computer
  3. AC in and power switch
- Front View
  4. Argon gas out to counter
  5. USB to counter
  6. Air out
  7. DC power to counter
  8. Connection to motor enclosure
- Top View (Cover Removed)
  9. Power supplies: AC/DC converters to supply power to all systems.
  10. Flow control: Electronically controls flow rate.
  11. Optical isolation: Isolates motor when it's not in use, to prevent excessive noise pickup.
  12. Air pump: Pumps air into the outer chamber of the counting module to prevent argon buildup.

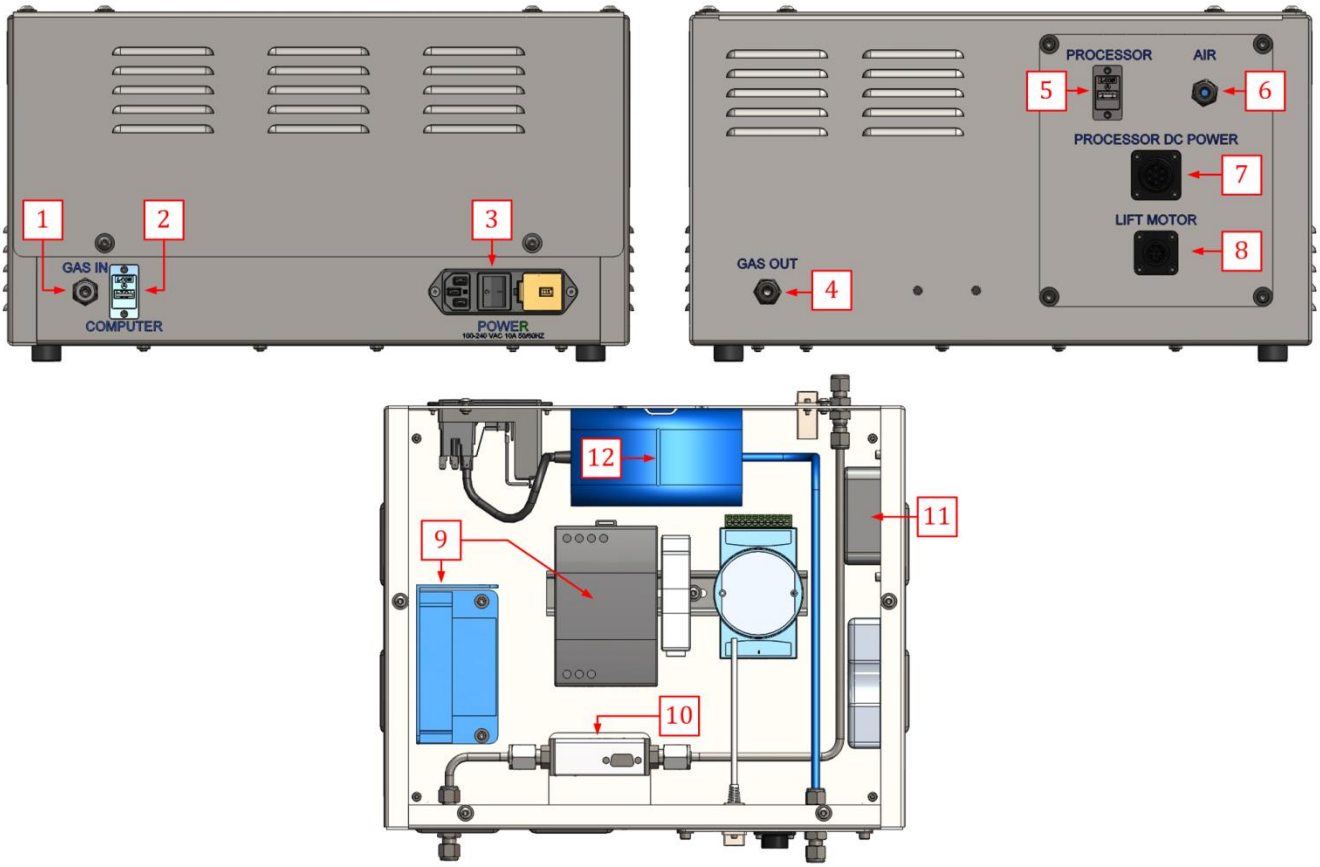


Figure IV-3: Top left: rear view of support box. Top right: front view of support box. Bottom: top view of support box with cover removed.

B. Requirements and Specifications

This section is a brief overview of the various specifications and requirements for the UltraLo-1800.

Requirement	Specification
Rated Voltage	100-240 (± 10%) VAC
Rated Frequency	50/60 Hz
Typical Current (Counter + Laptop)	0.7 A
Typical Power (Counter + Laptop)	0.08 kW
Max Power	0.100 kW
Gas Type	Argon
Pressure	21 PSI (150 kPa) ± 5%
Tubing	¼" OD metal tubing

Component	Width (in)	Depth (in)	Height (in)	Weight (lbs)
Counter Module (closed)	34.3 (87.1 cm)	40.0 (101.6 cm)	27.0 (68.6 cm)	330 (150 kg)
Counter Module (open)	34.3 (87.1 cm)	40.0 (101.6 cm)	45.3 (115.1 cm)	330 (150 kg)
Counter Module (tray ext)	34.3 (87.1 cm)	66.0 (167.6 cm)	27.0 (68.6 cm)	330 (150 kg)
Support Module	16.0 (40.6 cm)	12.0 (30.5 cm)	8.5 (21.6 cm)	30 (13.6 kg)
Laptop	13.5 (34.3 cm)	9.5 (24.1 cm)	10.5 (26.7 cm)	5 (2.2 kg)

C. Counter Manipulations

Sometimes in the course of maintenance or troubleshooting it may become necessary to perform certain manipulations on the UltraLo-1800. This section is a repository of common manipulations. In fact, other than opening the counter, it's unlikely that you will need to do any of these. As always, you should not perform any of these without good reason, and, except for adjusting the tray height, only under the instruction of an XIA technician.

1. Adjusting the Tray Height

Tools: None.

The tray on the UltraLo-1800 is designed to adjust vertically in order to accommodate samples up to 1/4" thick. To adjust the tray height:

1. Eject the tray, pull it all the way out of the counter.
2. Remove the tray and the perforated support, set them aside.
    a. Note: removing these trays is slightly easier if you lower the tray handle by pulling out the two black knobs on the tray's sides (you can turn these knobs slightly while they are pulled out to lock them in the out position).
3. You will now see eight metal blocks with numbers on them. The numbers indicate the height of that face of the block, all 3 pairs of faces are different. The tallest is 1.440, which corresponds to a full-height tray. Rotating the blocks so 1.315 faces up will lower the tray 1/8", and rotating them so 1.190 faces up will lower the tray 1/4".
4. Once the blocks are all at the same desired position, put the trays back on, making sure that they are seated on the blocks.
    a. Note: if you pulled out the black knobs, reinsert them now.
5. Push the tray pack in and close it via CounterMeasure.

This operation may be performed as needed to accommodate samples of substantial height.

2. Opening the Counter

Tools: One 5/8" box wrench; two 9/16" box wrenches; one 3/8" hex key (supplied with counter).

The counter will need to be opened periodically for maintenance (see **Annual Maintenance**). To open it:

1. Close CounterMeasure and turn off the power switch on the **Support Box**.
2. Wait about 20 seconds for the residual high voltage to drain.
3. Use the wrenches to unhook the rigid gas tube.
4. Remove the two side fairings by gently pulling them off, and set them aside.
5. Then remove the hex key from the rigid gas tube and use it to open the 4 latches on the side of the counter.
6. Lift the upper chamber to open the counter. The gas springs will provide assistance with opening, but be careful nonetheless.

To close the counter, simply reverse the process: lower the upper chamber; latch the latches; put on the side fairings; connect the rigid gas tube; and finally turn the power back on.

3. Removing a Side Panel

Tools: One 1/8" hex key.

This operation should only be done at the request of an XIA Technician.

Very occasionally an XIA technician will request you to open a side panel for troubleshooting or maintenance. To do this:

1. Close CounterMeasure and turn off the power switch on the **Support Box**.
2. Wait about 20 seconds for the residual high voltage to drain.
3. Use the hex key to remove the ten screws on the panel.
4. Pull off the panel. Removing the panel from the side may take some force, as there is slightly tacky silicone rubber between it and the counter body to serve as a vibration reducer.
5. Set the panel and screws aside.
6. To replace the panel you will need to carefully align the first few screws, as the panel sits slightly above the surface.

4. Opening the Support Box

Tools: One 1/8" hex key.

This operation should only be done at the request of an XIA Technician.

This is essentially the same as removing a side panel, but there are only 6 screws and they're not all located on the same surface. See **Support Box** for an image of where they are located. As with opening the side panel, make sure to turn the support box off before opening it.

5. Opening the Electronics Box

Tools: One 3/32" hex key.

This operation should only be done at the request of an XIA Technician.

Depending on the height of the UltraLo-1800's table, you may want a step-ladder to open the electronics box. As always, don't perform this procedure unless instructed. First, turn off the power switch on the **Support Box**. Next, using the hex key, remove the six screws. Set aside screws and panel for reinstallation later.

V. Maintenance/Calibration

A. Calibration

Calibration is initially performed at XIA, prior to shipment, and should be considered valid for up to a year. To ensure that your UltraLo-1800 continues to perform optimally over an extended period, XIA recommends enrolling in the Compliance/Calibration program. This program will verify that your system is producing results that conform to and comply with industry standards.

If you suspect that your UltraLo-1800 needs calibration, or are interested in learning more about the Compliance/Calibration program, please contact XIA at support@xia.com.

B. Weekly Maintenance

There is not much maintenance needed on a weekly basis. We recommend that you regularly check ADC traces (in the **Diagnostic Panel**) to familiarize yourself with the noise environment, so that if a change in the noise environment occurs it can be caught quickly.

C. Monthly Maintenance

There are only a few maintenance steps needed per month. Cleaning the tray, or any tray liner, regularly (using the method outlined in **Cleaning Procedure**) is highly recommended. This will help keep the background in the detector as low as possible. (If you change samples often you may want to do this more frequently than once a month.)

In addition, doing a run with a standard sample of your choosing to ensure that your background hasn't changed is also good practice.

D. Annual Maintenance

One annual maintenance step is to inspect and grease the seal around the door. To do this open the motor dialog and run the tray out. When door gets all the way down to the bottom, press "hard stop". Lightly grease the seal using a silicone lubricant, either using your finger or some appropriate tool. Once it is greased, tell the motor control dialog to continue ejecting the tray. Once it is ejected push it back in and close it, either through the dialog or the tray control button.

The second annual maintenance item is to check the air level of the inflatable vibration-dampening feet and fill them, if necessary. There should be about 3/8" space between the top of the foot and the bottom of the counter, and the top of the foot should be level and without bulges or divots. The feet can be filled with a standard bicycle or car tire pump. Be careful not to overfill, as this can damage the foot. If you add too much air you can bleed some out by pressing the metal pin at the center of the valve with a fingernail or a small screwdriver.

VI. CounterMeasure

A. Application Overview

1. Main Panel

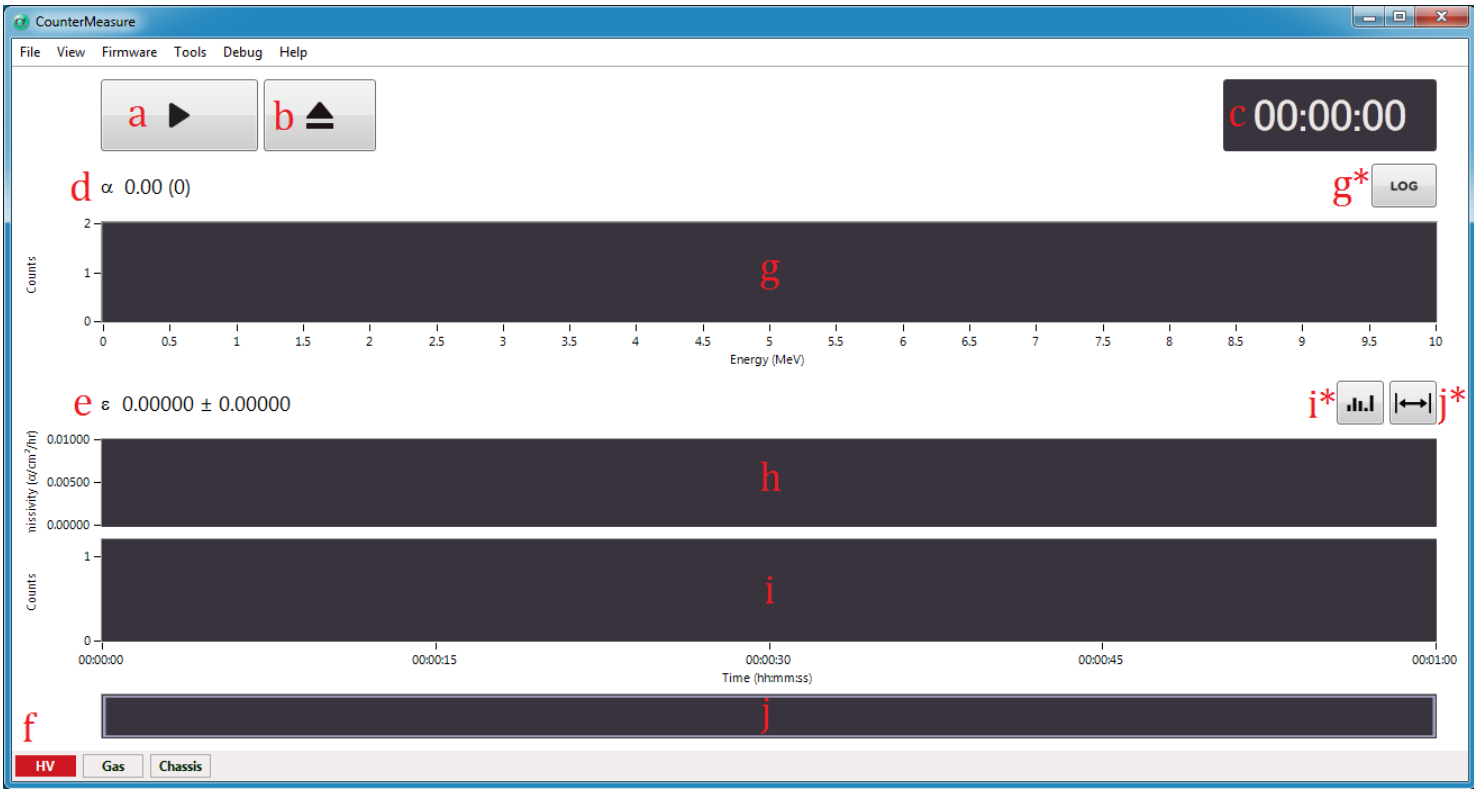


Figure VI-1: Normal view of the CounterMeasure Main Panel. The letters indicate the letter of the headings below, which are: a) Run Control Button; b) Tray Control Button; c) Run Clock; d) Alphas Counted; e) Emissivity Value; f) Status Icons; g) Alpha Energy Histogram Plot; h) Emissivity vs. Time Plot; i) Alphas Counted Time Series Plot; j) ROI Timeline Control.

The Main Panel, shown in Figure VI-1, is the main window of the application and is shown on application setup. It is where many of the most important features of CounterMeasure are located. These features, excluding the menus, are:

a) Run Control Button

When no run is active, it launches the **Start Run Dialog**. When a run is active, it will stop the run. It will be disabled whenever starting a run is not allowed, such as when the tray is ejected or when CounterMeasure couldn't connect to the electronics. (See **Can't Start a Run** for information on troubleshooting a greyed-out Run Control Button.)

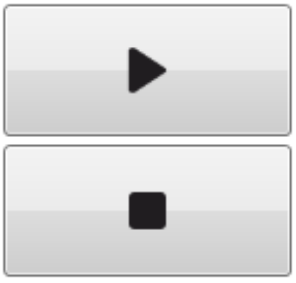


Figure VI-2: Run Control Button: top starts a run, bottom stops an active run.

b) Tray Control Button

Pressing the Tray Control Button will eject the tray and launch a dialog showing the tray's progress (1). When the tray is fully ejected the dialog shows whether it is fully pushed back (and therefore ready to be retracted, (2). Once it is ready to be closed the "Close Tray" button on the dialog is enabled (3) and pressing that will close the tray (4). See Figure VI-3 for screenshots.

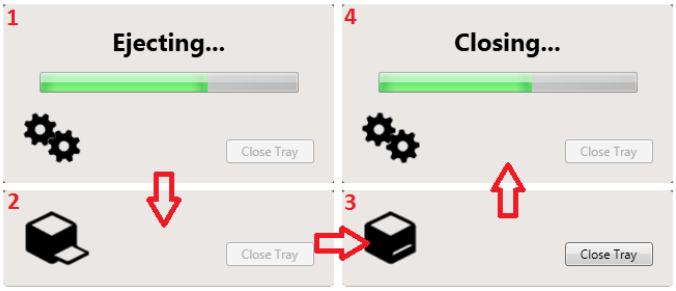


Figure VI-3: Tray Control Dialogs, with arrows showing the flow. Ejecting dialog (1), tray extended dialog (2), tray ready to close dialog (3), closing dialog (4).

c) Run clock

By default the Run Clock displays the amount of time remaining in the current measurement counting down, clicking the clock will change the display to time elapsed, counting up (shown in Figure VI-4).

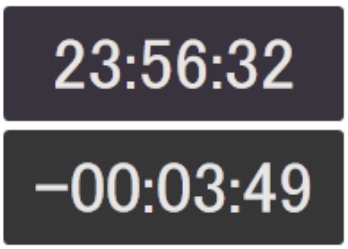


Figure VI-4: Run clock counting up (top) and down (bottom).

d) Alphas Counted

This is the number of alpha particles that CounterMeasure has observed. The number is shown as "Corrected (Observed)". The corrected alpha number takes into account efficiency losses. See **Counting Efficiency** for more information on this correction.

e) Emissivity Value

This is the current value of the emissivity and its error. At the end of a measurement this value represents the final emissivity of the sample. The emissivity is calculated in the usual manner ($\varepsilon = \alpha/A \cdot t$) where α is the corrected number of alphas, A is the current electrode size, and t is the elapsed time.

f) Status Icons

Status icons report on the status of three auxiliary systems on the UltraLo-1800: the high voltage bias; the flow controller; and the tilt sensor. These icons are grey when their status is appropriate for immediately starting a run and are red when some change is needed before a run can be started. In addition, there is an icon to indicate that the software was unable to connect to the system. For information on debugging these icons, see **Status Icons Red**.

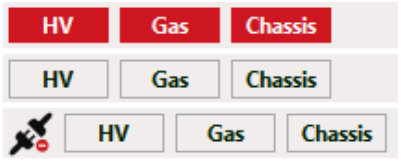


Figure VI-5: Status icons in various states: all inappropriate for running (top); all appropriate for running (middle); software disconnected from hardware (bottom).

g) Alpha Energy Histogram Plot

The top plot is a histogram of the energies of all alpha particles observed in the measurement and runs from 0 to 10 MeV. This plot has zooming and panning enabled to allow closer inspection of features

in the histogram. For more information on zooming and panning, see **Zoom and Pan**. Finally, the button indicated as **g*** will toggle the y-axis of the histogram between linear and logarithmic scales.

h) Emissivity vs. Time Plot

The second plot is the evolution of the emissivity, and the error in the emissivity, versus measurement time. The most recent value (the right-most value on the plot) is the same as the value reported in **Emissivity Value**. This plot is useful diagnostically as it allows the user to look for systematic changes over time. For instance, a slow rise in emissivity could indicate that there were problems with moisture early in the run, and a sharp drop could indicate radon exposure. For more on using this plot for diagnostics, see **Troubleshooting**.

i) Alpha Counts Time Series Plot

The final plot is a histogram of alpha counts in time. This plot depicts the number of alphas observed in a given interval of time and is similar to the Emissivity vs. Time plot. This chart can be hidden using the button indicated as **i*** in Figure VI-1.

j) ROI Timeline Control

The ROI Timeline control allows you to focus on any window of time that you are interested in. To set a ROI window, click either edge of the control and drag it toward the other edge. The times displayed on the edges of the control indicate where the ROI window boundaries are set within the total measurement time. When the ROI Timeline control is activated the rest of the Main Panel will display only data from the selected window (to see the ROI in action, see Figure VI-6). Additionally, any reports generated or data exported will contain only data from the ROI. This is useful for eliminating unwanted

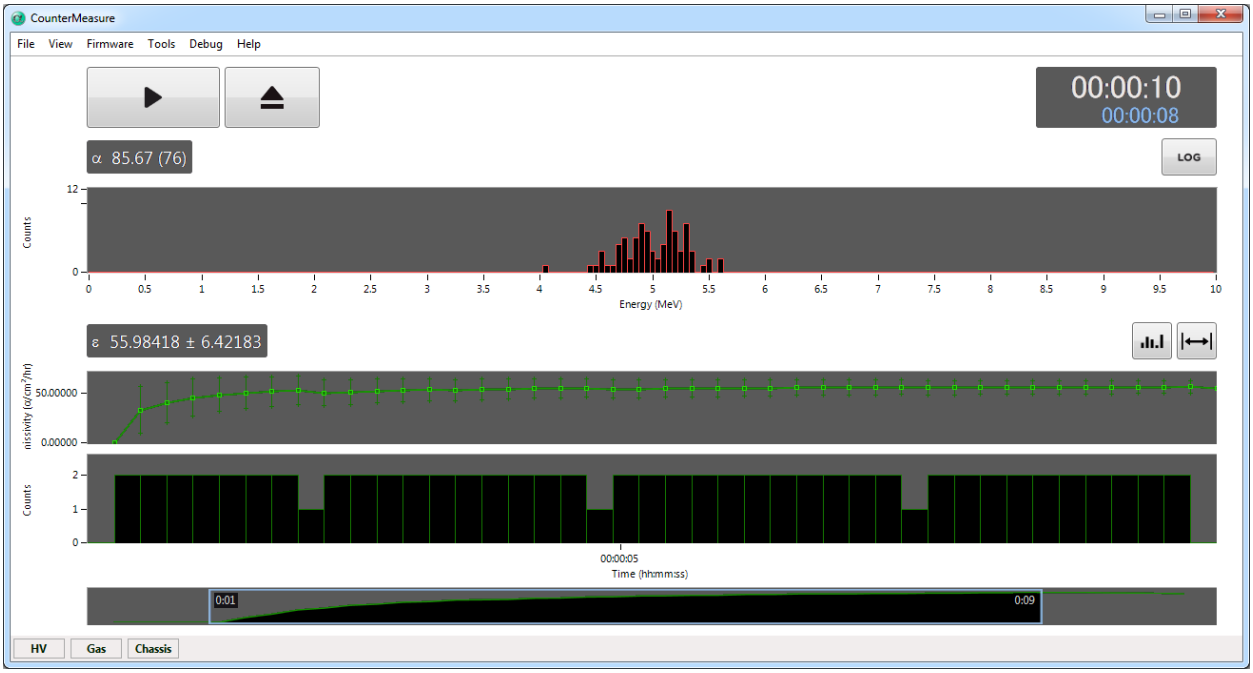
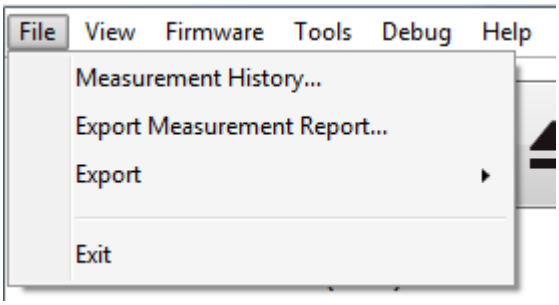
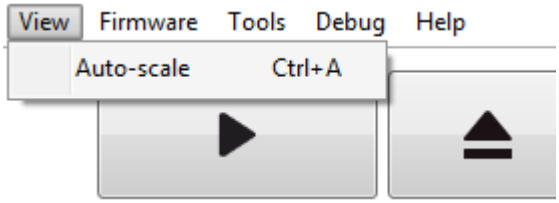
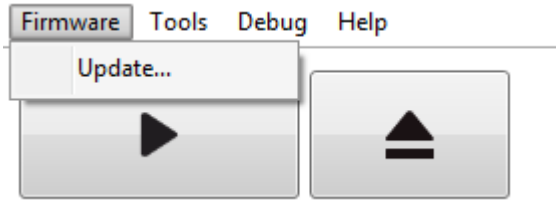


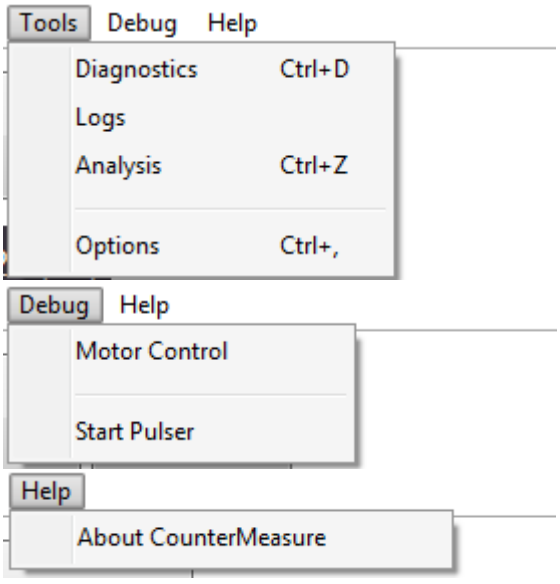
Figure VI-6: Main Panel with an ROI set. All plots are updated to display only data from the selected time window. The emissivity value and alphas counted are also updated. The Run Clock displays both the total measurement length and the ROI length. Both ends of the ROI show the time they're at.

transient signals, such as radon or moisture, without having to do another run. The ROI can be hidden using the button indicated as **j*** in Figure VI-1. You can remove the ROI selection either by sliding the bars back, double-clicking inside the ROI control window, hitting Ctrl+A, or going to the *View* menu and selecting “Auto-scale”.









At the very top of the Main Panel is a series of menus:

k) File

File menu allows you to exit the program, open the **Measurement History** window, or generate **Exports and Reports**. File generation via export menu options is not possible during a measurement.

l) View

The *View* menu's sole option, "Auto-scale" allows you to remove an ROI window if one is set. This option is unavailable if there is no ROI set.

m) Firmware

The *Firmware* menu allows you to launch the **Firmware Update Dialog**. This option will be disabled during a measurement or if the software didn't connect to the counter.

n) Tools

Tools provides access to the **Diagnostic Panel**, the log window (see **Generated Files** for more details on logs), the **Analysis Panel**, and the **Options Dialog**. The Diagnostics Panel will be unavailable during a measurement.

o) Debug

The *Debug* menu contains a few debugging tools, such as a motor controller interface and a pulser toggle. Most users should never need to use these.

p) Help

The help menu has one option, "About CounterMeasure", which contains information on software and firmware version numbers, as well as links to the support@xia.com and http://support.xia.com addresses.

2. Analysis Panel

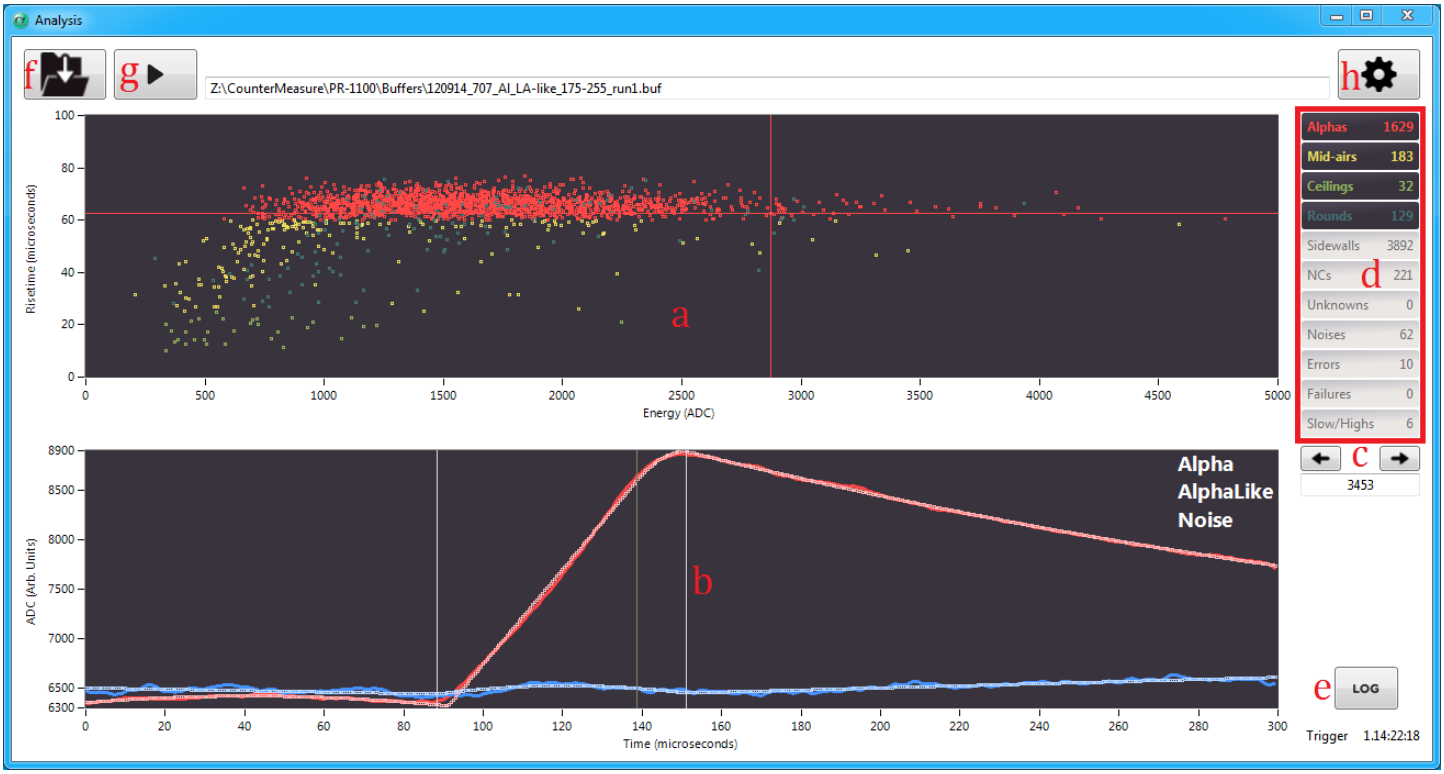


Figure VI-7: Analysis Panel with data shown. The letters indicate the letter of the headings below, which are: a) Event Scatter Plot; b) Event Trace Plot; c) Left/Right Buttons; d) Event Classifications and Counts; e) Log Button; f) Open Button; g) Analyze Button; h) Options Button.

The Analysis Panel contains detailed information on the UltraLo-1800's pulse-shape analysis and event classification results. It is launched from the *Tools* menu on the Main Panel.

a) Event Scatter Plot

This plot shows the scatter of Anode Energy vs. Risetime for all Alpha-Like events, which can be clicked to display the traces associated with that event in the event trace plot below (b). The colors correspond to the event classes shown in **d)**. When an event is selected cursors appear to highlight the selected event and can be dragged to select other events. This plot can be zoomed/panned, as described in **Zoom and Pan**. It can also be used to troubleshoot issues that may rarely arise, as described in **Counting Issues**.

b) Event Trace Plot

This plot shows the raw digitized waveforms for the selected event and the fits from their analysis. The anode trace is red, the guard trace is blue, and the fits are light red and blue. Occasionally a yellow trace will be present, this is the add-back pulse discussed in **Induction**. The vertical lines are the times of the three timing parameters (t_0, t_S, and t_R, from left to right) discussed in **Electrostatic Description of the UltraLo-1800**. The text displayed in the upper right-hand corner are, from top to bottom, the event classification, anode trace classification, and guard trace classification (the meaning of these classifications is also discussed in **Alpha Analysis Engine**). By right-clicking on the plot you can hide the

fits or export a zip file containing the traces and the analysis log file (see **Exports and Reports**). This plot can be zoomed/panned, as described in **Zoom and Pan**.

c) Left/Right Buttons

Left/right buttons: Scroll through events sequentially, in the order they were captured, one at a time. The left/right arrows on the keyboard have the same effect, as does pressing the Ctrl+N or Ctrl+P keys. The trigger number of the current event is displayed beneath the left/right buttons.

d) Event Classifications and Counts

Displays the classifications and number of each event type observed in the measurement. Clicking on an event class will toggle the visibility of the associated events in the Risetime vs. Anode Energy scatterplot and determine whether it will be skipped while scrolling. This is a convenient way to closely inspect the traces in a certain event class without having to scroll through all the rest. All event classes are initially toggled on. The event classes with a grey background aren't displayed in the Risetime vs. Anode Energy scatterplot plot because they don't have a well-defined risetime, but they will be scrolled through. The numbers and rates of events can be a useful diagnostic tool, for more information see **Troubleshooting**.

e) Log button

Shows the Alpha Analysis Engine (AAE) log file instead of the trace. Used for diagnostics. Underneath is the trigger time for the displayed event.

f) Open button

Opens a file for re-analysis. Click the button, navigate to where the file is stored, and open the file. The filename will now be populated in the text box next to the button. This button, along with the text box and the other buttons in this row, will disappear during data acquisition.

g) Analyze button

After opening a file, click to analyze it. CounterMeasure will analyze the file as though the data were being actively taken, and display the results as it analyzes. This button will be disabled when there is no file selected and disappear during data acquisition.

h) Parameters Button

Opens the **Options Dialog**. Like the other buttons in this row, it will disappear during data acquisition.

3. Diagnostic Panel

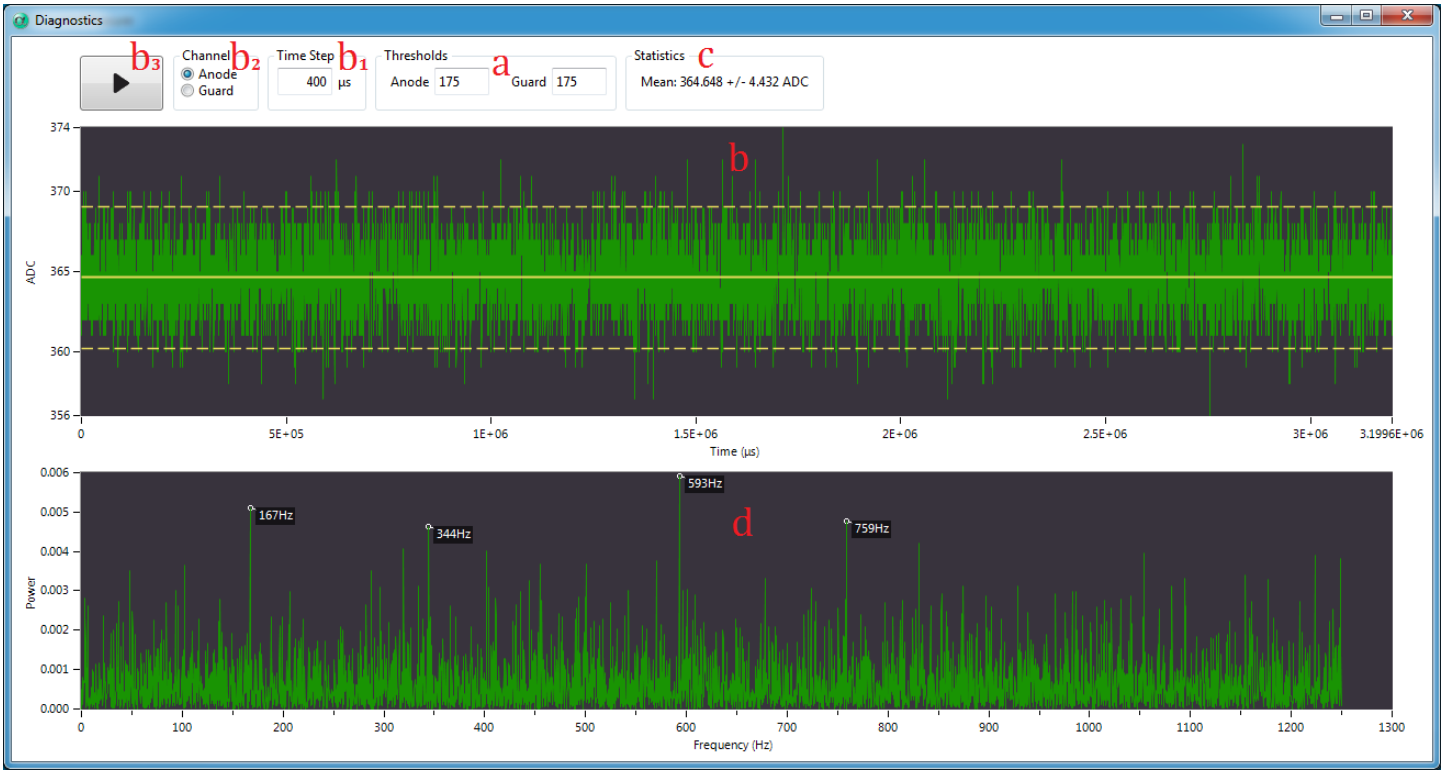


Figure VI-8: Diagnostic Panel with Anode trace and FFT displayed. The letters indicate the letter of the headings below, which are: a) Trigger Thresholds; b) Oscilloscope Plot; b_{1-3}) Parameters associated with Oscilloscope Plot; c) Statistics Box; d) FFT Plot.

The Diagnostic panel is the final of the three primary panels. It is mostly used for debugging or checking for changes in the noise environment. It cannot be launched during a measurement or when the hardware is not connected. It is launched from the *Tools* menu on the Main Panel.

a) Trigger Thresholds

Trigger thresholds on the Anode/Guard. These come pre-set from XIA. Unless the UltraLo-1800's noise environment changes rather dramatically they should never need changing. If the thresholds are set too low (around 100-125) the electronics will trigger on detector noise, and if they're too high low-energy alphas might not be detected. Experimentation at XIA has found that 175 on the Anode and 255 on the Guard are good choices. The units are arbitrary, but the choice of 175 corresponds to a cutoff of about 1.5 MeV, with higher thresholds cutting off at higher energies, and lower threshold cutting off at lower energies.

b) Oscilloscope Plot

The Oscilloscope plot displays 8000 raw ADC values of a selected channel collected at a chosen sampling interval. To select a sampling interval, enter a time into the Time Step box (**b_1**). The valid range of time steps is from 0.125 µs to 400 µs, so a time step of 400 µs has a total duration of 3.2 seconds. Different time steps will emphasize different frequency ranges. To select a channel use the Channel (**b_2**)

radio buttons, which switch between taking a trace from the Anode and the Guard. Finally, to collect a trace simply hit the Acquire Trace button (**b_3**).

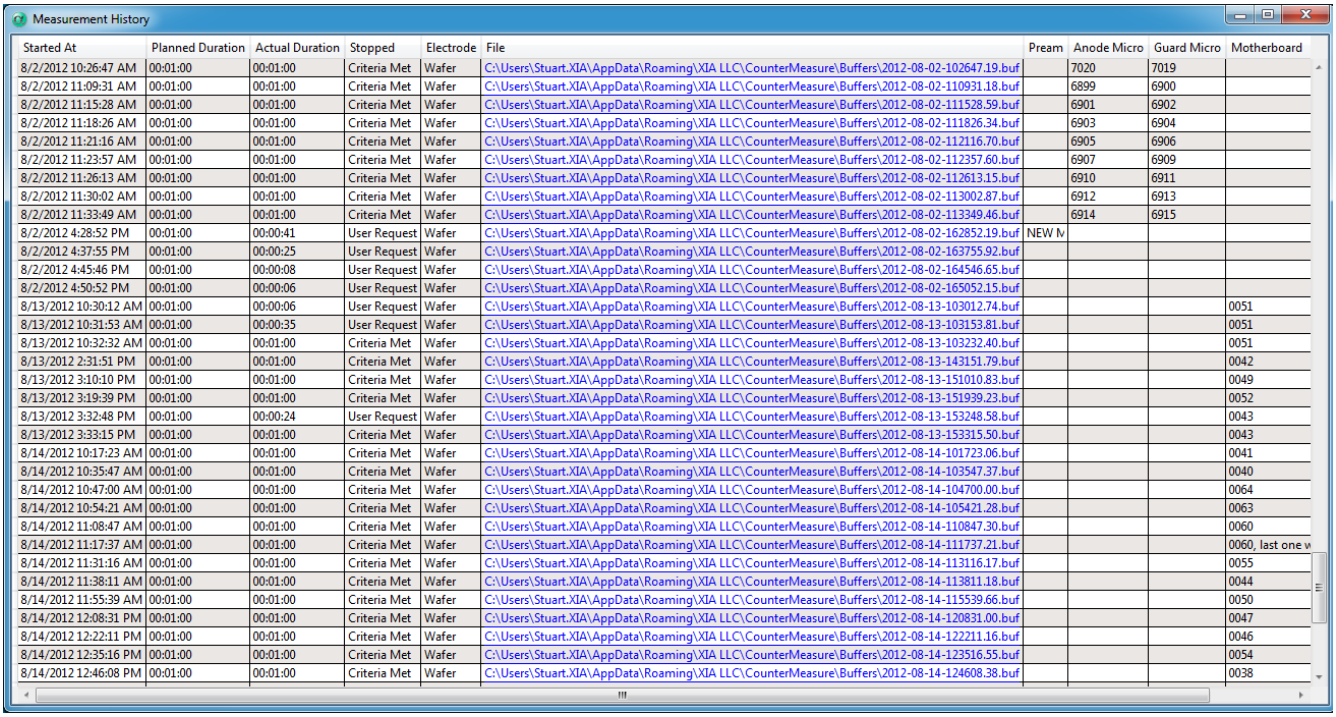
c) Statistics Box

The statistics box shows the mean value and the 2σ variance of the raw ADC trace. These correspond to the solid yellow line and the two dashed yellow lines, respectively.

d) Fast Fourier Transform Plot

The Fast Fourier Transform (FFT) plot shows the FFT of the raw ADC trace and what frequencies are present in it. The four largest peaks are identified and highlighted in the plot. When the sampling interval is appropriate, you will usually see a peak at 60 Hz and several harmonic peaks at 120, 180, etc, which may have power values greater than 1. There shouldn't be peaks above 1 in power at any other frequencies. If you see any, or if the peaks at the harmonics of 60 are above 10 in power, consult **Troubleshooting**. **Zoom and Pan** are both enabled on this plot.

4. Measurement History



Started At	Planned Duration	Actual Duration	Stopped	Electrode	File	Pream	Anode Micro	Guard Micro	Motherboard
8/2/2012 10:26:47 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-102647.19.buf		7020	7019	
8/2/2012 11:09:31 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-110931.18.buf		6899	6900	
8/2/2012 11:15:28 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-111528.59.buf		6901	6902	
8/2/2012 11:18:26 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-111826.34.buf		6903	6904	
8/2/2012 11:21:16 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-112116.70.buf		6905	6906	
8/2/2012 11:23:57 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-112357.60.buf		6907	6909	
8/2/2012 11:26:13 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-112613.15.buf		6910	6911	
8/2/2012 11:30:02 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-113002.87.buf		6912	6913	
8/2/2012 11:33:49 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-113349.46.buf		6914	6915	
8/2/2012 4:28:52 PM	00:01:00	00:00:41	User Request	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-162852.19.buf	NEW M			
8/2/2012 4:37:55 PM	00:01:00	00:00:25	User Request	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-163755.92.buf				
8/2/2012 4:45:46 PM	00:01:00	00:00:08	User Request	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-164546.65.buf				
8/2/2012 4:50:52 PM	00:01:00	00:00:06	User Request	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-02-165052.15.buf				
8/13/2012 10:30:12 AM	00:01:00	00:00:06	User Request	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-13-103012.74.buf				0051
8/13/2012 10:31:53 AM	00:01:00	00:00:35	User Request	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-13-103153.81.buf				0051
8/13/2012 10:32:32 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-13-103232.40.buf				0051
8/13/2012 2:31:51 PM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-13-143151.79.buf				0042
8/13/2012 3:10:10 PM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-13-151010.83.buf				0049
8/13/2012 3:19:39 PM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-13-151939.23.buf				0052
8/13/2012 3:32:48 PM	00:01:00	00:00:24	User Request	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-13-153248.58.buf				0043
8/13/2012 3:33:15 PM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-13-153315.50.buf				0043
8/14/2012 10:17:23 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-101723.06.buf				0041
8/14/2012 10:35:47 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-103547.37.buf				0040
8/14/2012 10:47:00 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-104700.00.buf				0064
8/14/2012 10:54:21 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-105421.28.buf				0063
8/14/2012 11:08:47 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-110847.30.buf				0060
8/14/2012 11:17:37 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-111737.21.buf				0060, last one v
8/14/2012 11:31:16 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-113116.17.buf				0055
8/14/2012 11:38:11 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-113811.18.buf				0044
8/14/2012 11:55:39 AM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-115539.66.buf				0050
8/14/2012 12:08:31 PM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-120831.00.buf				0047
8/14/2012 12:22:11 PM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-122211.16.buf				0046
8/14/2012 12:35:16 PM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-123516.55.buf				0054
8/14/2012 12:46:08 PM	00:01:00	00:01:00	Criteria Met	Wafer	C:\Users\Stuart.XIA\AppData\Roaming\XIA LLC\CounterMeasure\Buffers\2012-08-14-124608.38.buf				0038

Figure VI-9: Measurement History dialog from one of XIA's counters.

The Measurement History dialog is the interface to CounterMeasure's database of measurements. It can be opened from the *File* menu on the Main Panel. Every measurement started gets an entry in the database. The interface is a series of columns, with each row indicating a given run. Clicking on a column header will sort it alphabetically. The following columns are default:

1. Started At: This is the time the Run Control Button is pressed to start a measurement. If there was a purge counting will start 45 minutes after this time.
2. Planned Duration: The duration entered into the Start Run Dialog
3. Actual Duration: The actual duration of the measurement (not including purge time), which will be different from Planned Duration if the measurement is stopped early for some reason (see below).
4. Stopped: Notes the reason measurement ended. Reasons include:
    a. Criteria Met: The measurement went for the planned duration.
    b. User Request: The user stopped the measurement, either by pressing the "Stop" button or by exiting the program.
    c. Box Opened: The top of the counter was opened while a measurement was going.
    d. HV Dropped: The HV bias deviated from its defined operating limits.
    e. Flow Dropped: The gas flow deviated from its defined operating limits.
    f. Communication Lost: Communication with the counter was interrupted somehow, typically either through the USB connection coming unplugged or the line power to the counter being interrupted.
    g. Not Stopped: The measurement is currently running.

5. Electrode: The electrode configuration chosen in the Start Run dialog
6. File: The location of the data file generated. Clicking the link will open a Windows Explorer window with the data file selected.

In addition to the defaults listed above, the Measurement History Dialog displays any custom parameters you have defined in the **Options Dialog**. Each custom parameter will have its own column, and text entered into the **Start Run Dialog** will be displayed in the corresponding row.

5. Start Run Dialog

The Start Run Dialog launches whenever a measurement is started, which is done by clicking the Run Control Button. As shown in Figure VI-10 it contains five distinct parts:

a) Acquisition Time

The Acquisition Time box is where you will set your desired measurement length. The box is designed to be smart and recognizes many different syntaxes for run length. For example, to run for 1 day, 2 hours, 3 minutes, and 4 seconds, you can enter “1d 2h 3m 4s”, or “1.2:3:4”, or even “1 day, 2 hours, 3 minutes, 4 seconds”. Not all of these parameters need to be entered every time, “1d” is a valid time, as is “1d 4s”. The box will indicate an invalid time by turning its border red, if the border remains normal the time entered is valid. Finally, the box saves the 5 most recently used durations, and will auto-complete them as the user types if one is matched. They can be selected via the pull-down arrow. Note that this time does not include the purge time (which is normally 45 minutes, see next section).

a) Purge Check-Box and Duration

Most of the time you will be switching samples between each measurement, which requires a purge. Occasionally you may want to start a run without purging in order to remeasure the current sample. In this case simply uncheck the purge box and the run will begin immediately after hitting the Start button. CounterMeasure will remember whether the box was checked on the previous run and keep that setting for the subsequent measurement.

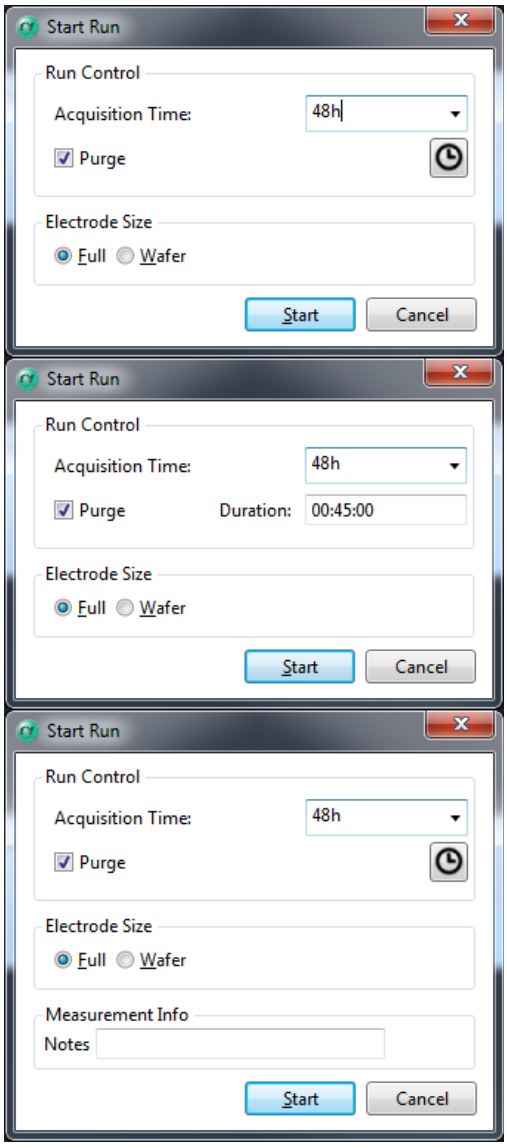


Figure VI-10: Start Run Dialog, default (top), with Purge Duration box shown (middle), and with custom parameter “Notes” (bottom).

Underneath the Acquisition Time box is a small clock symbol, clicking it will reveal the Purge Duration box (see Figure VI-10, top and middle). This box sets the purge duration, which is by default set to 45 minutes. This value can be changed in the same manner as the Acquisition Time box. The only situation where we recommend changing the value is to conduct a longer purge after the counter was opened (or otherwise without purge gas) for an extended period of time. In this case the duration should be increased proportionally to how long the counter was open (being open for 5 minutes may only require a 70-minute purge, being without gas for a week may require a 2-hour purge). This value is not remembered run-to-run, it will always revert to 45 minutes after being changed. Finally, we strongly recommend never setting this value below 45 minutes, as that’s the minimum required time for the chamber to completely purge.

b) Electrode Size

These are radio buttons that set the electrode size, with "Full" being the 1800 cm^2 electrode configuration and "Wafer" being the 707 cm^2 electrode configuration. For more on the differences between these configurations and when to use them, see **Secondary Veto Channel**.

c) Measurement Info

These are a series of blank boxes that accept arbitrary text input to be stored in the measurement database, with labels defined by customer parameters. These parameters can be anything set up by the user, as discussed in **Options Dialog**. Sample serial number or ID and sample description are two that XIA has found useful. Unlike duration, these values will not be remembered from run to run. This section will only appear once custom parameters are created.

d) Start/Cancel buttons

The Start button starts the measurement, while the cancel button closes the dialog without starting one. If the Purge box was checked, the purge will begin after pressing "Start" (see Figure VI-11), unless the HV needs to be ramped, in which case the high voltage will be ramped first, then the purge will begin. During a purge the rest of CounterMeasure will be unavailable, the only possible interactions are canceling the purge (which also cancels the measurement) and skipping the purge (which will immediately start a measurement).

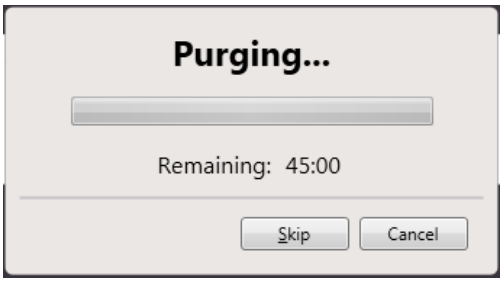


Figure VI-11: Purge Dialog.

6. Options Dialog

CounterMeasure has relatively few user-adjustable settings. They are: a) the Alpha Analysis Engine's (AAE) parameters; and b) the user's custom parameters for the Measurement Database. Both of these are set in the same dialog, accessed either by Ctrl+, or by navigating to *Tools* and then clicking on *Options*.

a) AAE Parameters

The AAE parameters are used by the analysis engine to classify pulses, and are determined based on the noise characteristics of your detector. Once measured in a specific location and with specific hardware, they are quite stable and seldom need to be changed. This measurement will initially be performed when the counter is installed. If the noise conditions for a given machine change, XIA will provide instructions for updating the parameters. Please note that changing these parameters without a deep understanding of their functions can easily lead to erroneous pulse analyses and measurement results.

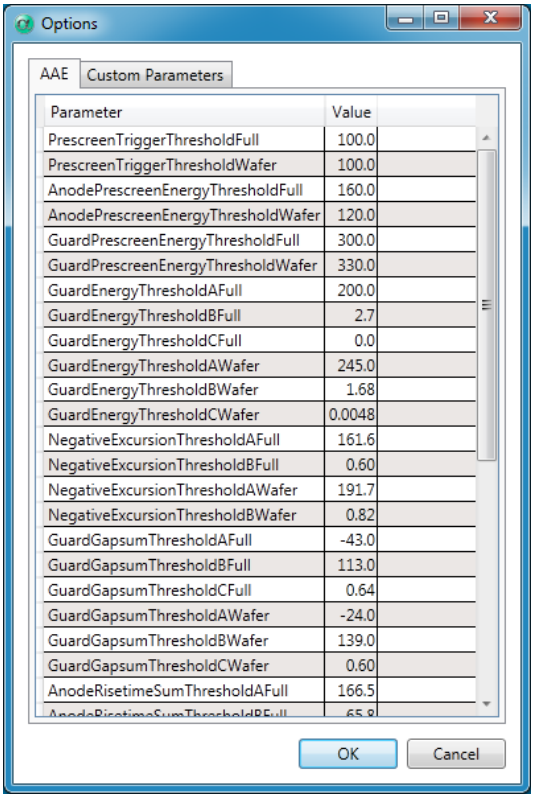


Figure VI-12: AAE Parameter options

b) Custom Parameters

The Custom Parameters are user-specified descriptions of data and info to be tracked with the measurement, and can be anything that suits the user's needs. Making a new parameter adds that column to the **Measurement History** dialog (the column will be empty for any preceding measurements). The parameter is also added as a field in the **Start Run Dialog**. These fields can be renamed or deleted. Note that if a field is deleted the existing entries are saved. If a field with the same name is created, that column in Measurement History will then be repopulated with the old entries as well.

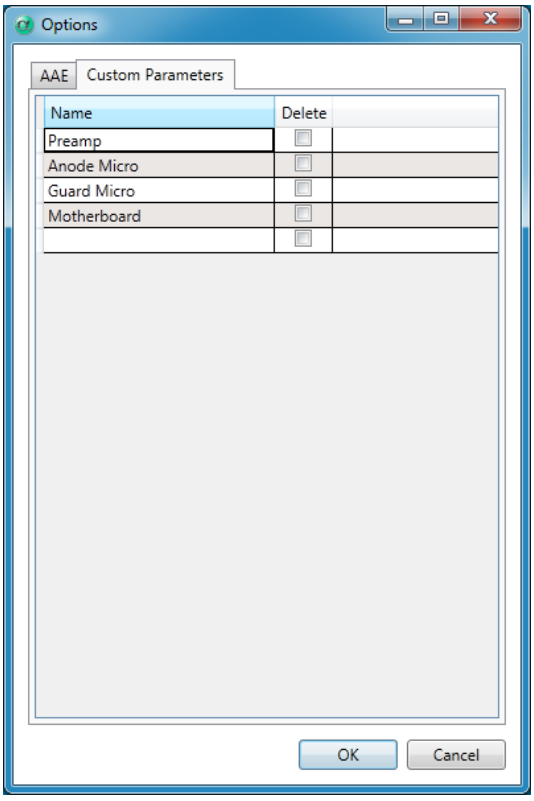


Figure VI-13: Custom Parameter options.

7. Firmware Update Dialog

The Firmware Update dialog (shown in Figure VI-14) is the method by which CounterMeasure installs new firmware for the electronics. If there is a firmware update included with a new release of CounterMeasure it will launch automatically the first time the new version of CounterMeasure connects to the hardware. It can also be launched manually by going to the *Firmware* menu and clicking "Update…".

Once launched, the dialog needs to be pointed to a firmware file. In the case of an automatic launch the file location will be automatically filled out. If XIA has supplied you with a different firmware file, simply click the "…" button and use the explorer window to navigate to the file and double-click it. Once a file is selected, click the "Update" button. Note that this will trigger Windows' User Account Control, and you will need to give the application permission to perform the update. The updater will then launch a Windows Command Prompt, which will perform the update and then close. The Firmware Update dialog will then close and the firmware will have been updated.

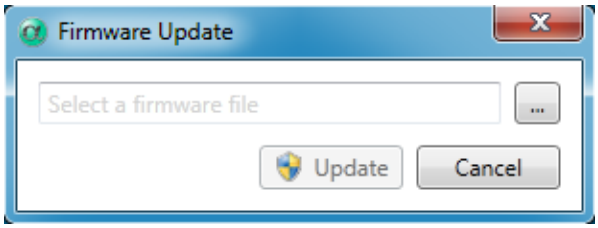


Figure VI-14: Firmware Update dialog. In the event of new firmware on update, the firmware file will be automatically selected.

B. Common Interactions

There are several ways of interacting with the various plots and buttons in CounterMeasure that aren't immediately obvious at first glance. This section will detail those methods of interaction and where they occur, and explain their uses.

1. Tooltips

Tooltips are very common in CounterMeasure. Most buttons and text entry locations have tooltips that explain their purpose. To see a tooltip simply hover the cursor over the control that you're interested in for a moment; if a tooltip exists it will pop up.

Two example tooltips are shown in Figure VI-15. The **Start Run Dialog** has one explaining how enter the duration of the run, and the Status Icons will show you the current reading.

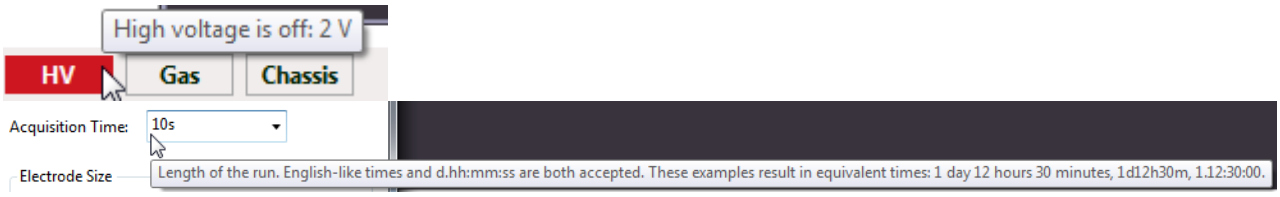

High voltage is off: 2 V
HV
Gas
Chassis
Acquisition Time:
10s
Electrode Size
Length of the run. English-like times and d.hh:mm:ss are both accepted. These examples result in equivalent times: 1 day 12 hours 30 minutes, 1d12h30m, 1.12:30:00.

Figure VI-15: Two example tooltips. The High Voltage Bias (top) and Acquisition Time (bottom)

2. Zoom and Pan

Sometimes you might want to get a closer look at a feature on a graph in CounterMeasure, such as a peak in a spectrum. Fortunately, many graphs (though not all) allow zoom and pan operations. To zoom, simply hold down the Shift key, which will cause the cursor to turn into a magnifying glass, and either draw a box around or click near the area you're interested in zooming in on. To zoom back out hold down the Shift key and right click. If you've zoomed in multiple times, you will need to zoom back out multiple times. To pan the plot you simply hold down the Ctrl key, which causes the cursor to turn into a hand, then click and drag the plot. To undo a pan hold down the Ctrl key and right click.

Zoom and pan work on the Alpha Spectrum, as well as all graphs in the **Analysis Panel** and the **Diagnostic Panel**. Examples of zooming and panning are shown in Figure VI-16, and a summary table is below this paragraph.

Operation	Method
Zoom In	Shift+drag or Shift+click
Zoom Out	Shift+right-click
Pan	Ctrl+drag
Undo Pan	Ctril+right-click

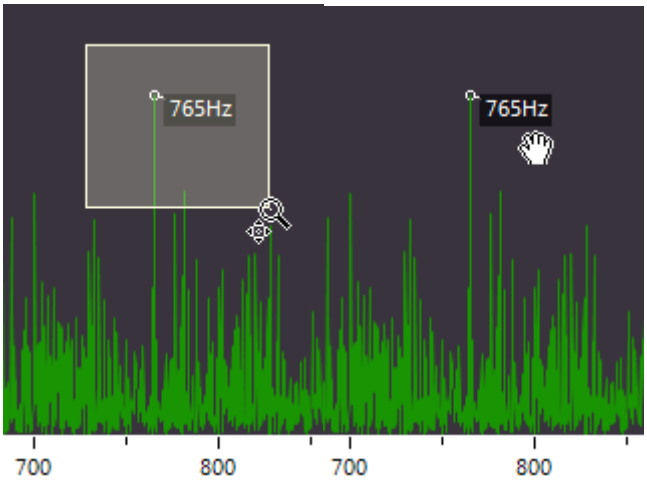


Figure VI-16: Examples of zooming (left) and panning (right), with associated icons.

3. Splitters

Several of the plots in CounterMeasure have adjustable heights relative to each other. These are the Emissivity Evolution and Counts plots on the Main Panel, and the ADC Trace and Fast Fourier Transform on the Diagnostics Panel. To adjust the relative heights press down your left mouse button on the bar between the plots. The cursor will change into the one pictured in Figure VI-17. While still holding down the left mouse button, you can drag the bar up or down. The change will be set upon release of the button, and persists through restarts of the application.

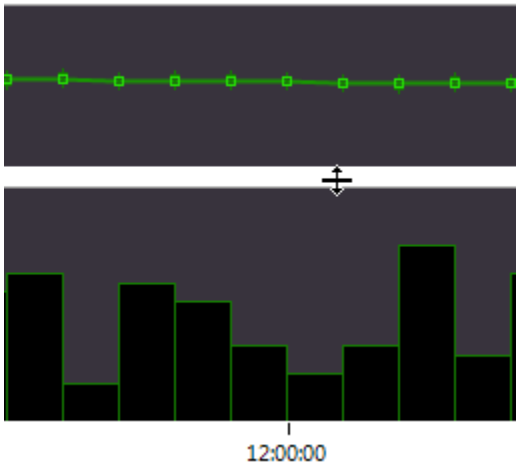


Figure VI-17: Splitter icon, shown between the Emissivity and Counts graphs.

C. Making a Standard Measurement

This section details the steps to take in order to make a typical measurement, first using a flowchart and subsequently via text.

1. Measurement Flowchart

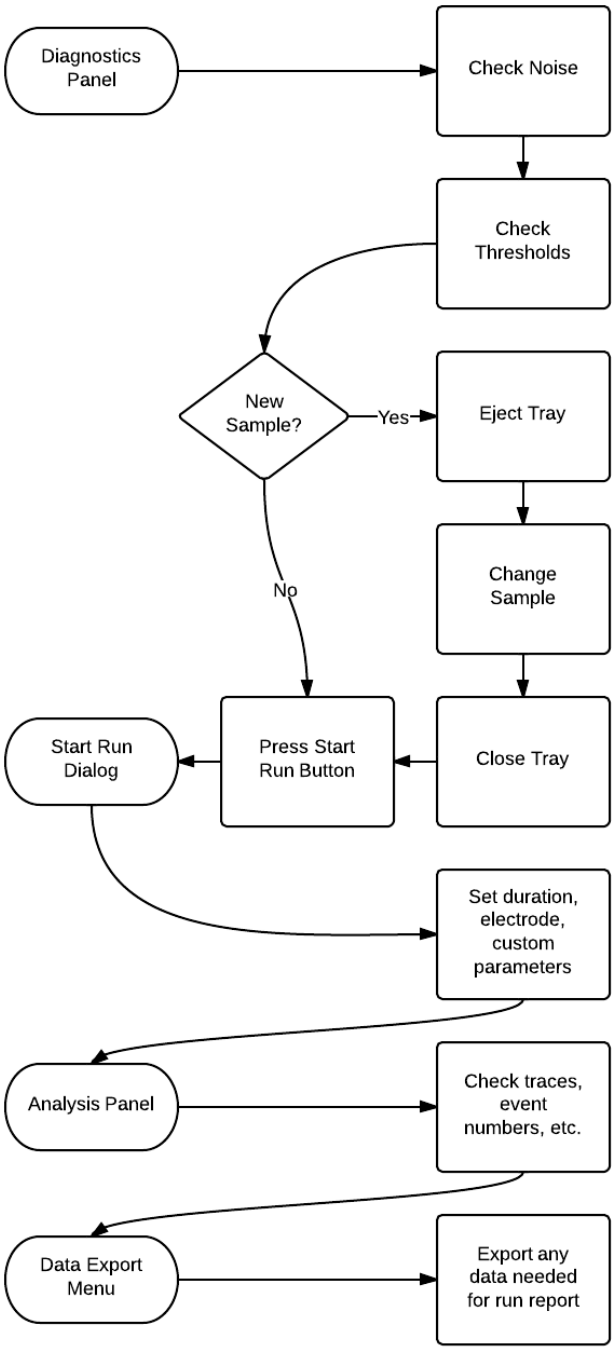


Figure VI-18: Measurement flowchart

2. Detailed Description

This section is intended to be a very thorough walkthrough of the experience of using CounterMeasure for routine tasks.

a) Starting the App

Upon starting CounterMeasure you'll see a loading screen while the software attempts to communicate with the hardware. This will take several seconds. You will be able to tell if the connection was successful based on the presence or absence of the "no connection" icon in the bottom-left corner, near the status icons. If you cannot connect to the counter, see **Can't Connect to Counter**.

b) Diagnostics Panel

Thresholds and Traces: Before starting a run there are a few things to check to ensure that the UltraLo-1800 is performing as expected. The first is to double-check that the thresholds are set appropriately (175 on the Anode and 255 on the Guard is standard). Once set they should not change on their own, but it is good to check anyway. The second is to take a few traces on both the Anode and Guard at various time steps. This allows the user to become familiar with the noise environment in the detector and notice changes in noise more quickly. For examples of noise on diagnostic traces and for more information about how to use the diagnostics panel to spot noise, see **Troubleshooting**.

c) Main Panel

Begin: If you are not changing samples please skip the next three steps and begin at "Start Run".

Eject tray: To change samples: hit the **Tray Control Button** to eject the tray.

Swap Samples: Remove the old sample, put on the new sample, all while being careful not to contaminate the sample. For more information see **Sample Handling**. In brief: do not handle the sample directly; use new gloves or cleaned tweezers; and be careful to clean all sample-handling instruments thoroughly.

Close tray: Gently push the tray all the way back into the counter, until it hits its stop. Hit the "Close" button in the Tray Control Dialog.

Start run: The next step is to start the run. If a purge is required (that is, if the sample was switched, the most common case), just hit the "Start Run" button on the Main Panel to launch the Start Run dialog. In the Start Run dialog choose the duration of the run (this does not include the purge time), choose the most appropriate electrode size, and fill in any custom parameters. After that the purge will happen automatically, and when it finishes the run will start.

Watch Data: During and after the run the information on the Main Panel can be extremely useful. The headline emissivity number is the goal of the measurement, but the graphs also provide other useful diagnostic information. For instance, if the Emissivity vs. Time graph shows a large drop through a run, there may be contamination from radon (see **Radon** for more information). The spectrum can give information on the specific isotopes in the sample. If there is a significant change over the course of the

measurement (say from outgassing or radon) the ROI can be used to select only good data (all graphs will update with only data from the selected time period). All of these graphs should be reviewed to ensure that the measurement was successful.

d) Analysis

Watch Data: If desired, the Analysis Panel can be opened while a measurement is in progress. More complete details are presented in the **Analysis Panel** section. Here we only wish to suggest how the information displayed can be useful for determining whether or not a measurement is proceeding well. For instance, the main graph, Anode Energy vs. Risetime, can show if there are issues with outgassing (see **Moisture**). Further, the rates of various event types (e.g. ceilings and rounds) should stay relatively constant from run-to-run. Excessive numbers of any kind of events can indicate a problem. Scrolling through some traces can show any abnormal noise that may have cropped up (such as vibration from unusual environmental activity). While the majority of runs will show no problems, spending a few minutes looking through the data can alert the user to potential issues early, before a day has been wasted taking bad data.

e) Run reporting

Exporting Files: After the run is over and the results have been checked thoroughly, the user will typically want to generate a report. This can be as simple as inserting the reported emissivity into a spreadsheet, or as complicated as running custom pulse-shape analyses. CounterMeasure facilitates reporting by having several different files available for export, most notably a full measurement report, as discussed in **Exports and Reports**. This export can be performed either immediately after a run ends, or later, after reanalyzing a file.

D. Generated Files

There are four important file types in CounterMeasure: buffers; logs; parameters; and exports.

1. Buffers

Buffer files, with the file extension .buf, are CounterMeasure's data storage files. The file is a custom binary format, and requires special tools to read. These files are located in C:\Users\UltraLo\AppData\Roaming\XIA LLC\CounterMeasure\Buffers. Buffer files are fairly small, an average run will only generate around 4 MB/day.

2. Logs

CounterMeasure produces several different log files. They are all located in C:\Users\UltraLo\AppData\Roaming\XIA LLC\CounterMeasure\Logs. These are the CounterMeasure log, the Handel log, the sensor log, and the analysis log.

a) CounterMeasure Log

The most immediately useful log is the CounterMeasure log, which is directly in that folder, or accessible from the Main Panel by navigating to *Tools* and clicking *Logs*. It is formatted in plain text and can be read by any text reader. This log contains information about CounterMeasure's interaction with the electronics and the support box, such as when it reads out events or when it reads the HV, moisture flow, and tilt sensors. It also contains information on errors. If there is an error that requires contacting XIA (support@xia.com), we will almost certainly ask to see this log file. When a CounterMeasure log gets too large (~52 MB) it is renamed and a new one is generated. CounterMeasure.log will always be the most recent log, CounterMeasure.log.1 the second most recent, and so on.

b) Handel Log

The second type of log, the Handel log (handel.log), is also stored directly in the logs folder with the CounterMeasure logs and is also a plain-text log. Handel is XIA's device interaction software, and CounterMeasure uses it to communicate to the hardware. This log is also useful in the event of an unexpected error. It is important to note that this log is overwritten every time CounterMeasure is launched, so in the event of an unexpected error be sure to save this log before attempting to restart CounterMeasure.

c) Sensor and Analysis Logs

The remaining two logs are stored in their own folders inside the Logs folder – these are Analysis and Sensor logs. Sensor logs (.sns) store data from the various sensors, such as the tilt, HV, and flow. These logs are binary-formatted. Analysis logs store logs from the analysis engine. They are plain-text logs. These logs are only pertinent to the user if there's an error with one of those particular systems, in which case XIA will ask for them.

3. Parameters

The parameter file is where the alpha analysis engine (AAE) stores the various parameters it uses to classify pulses. This log is stored in C:\Users\UltraLo\AppData\Roaming\XIA LLC\CounterMeasure\Config. These parameters vary from counter to counter and place to place, and

need to be updated whenever a counter is moved. These parameters can be updated through the Options menu (see **Options Dialog**).

4. Exports and Reports

CounterMeasure allows the export of a few different data files. Most users will be interested in the Measurement Reports, which are PDF files that can be generated by navigating to *File* and clicking on "Export Measurement Report…". A dialog (shown in Figure VI-19) will pop up, asking for a sample name, a description, and any pertinent notes. These will show up on the report itself, allowing the user to make each report distinct and immediately salient. After clicking "Save" on the dialog, you'll need to pick a filename and location to save the report. Then CounterMeasure will generate a report containing many useful pieces of information, such as the run emissivity and error, alpha counts, date, run length, electrode size, as well as the 3 plots on the **Main Panel**. An example can be seen in Figure VI-20. The exported data responds to a selected ROI, as discussed in **ROI Timeline**. Finally, this export can be performed upon reanalysis of a file, as discussed in **Analysis Panel**.

There are a few other exports available besides the Measurement Report. To export one of them, go to the Main Panel and navigate to *File* and click on "Export". There will be a list of five files available for export, Alpha Spectrum, Alphas, Alpha Time-series, Emissivity, and Analysis Results. These will all be comma-separated (.csv) files, and their contents are detailed in Table I.

The final export available is the fit export, available by right-clicking the Event Traces Plot in the **Analysis Panel**. It will export a .tar.gz file containing 4 files, a .trs containing the raw ADC values of the two traces, another .trs containing the fit values for both traces, and two log files.

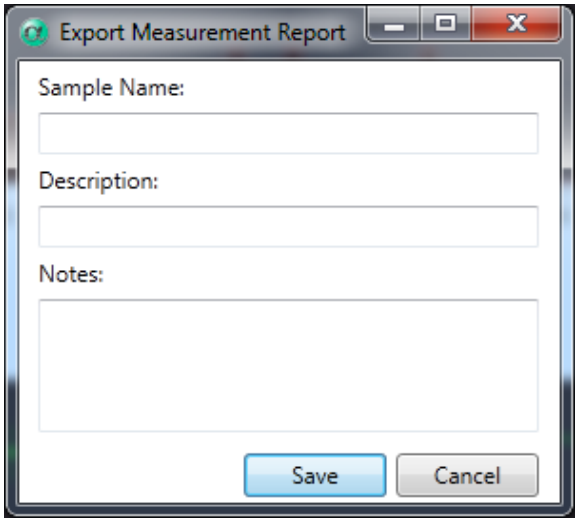


Figure VI-19: Export Measurement Report Dialog.

Exported File	Contents
Alpha Spectrum	Bin number in MeV vs. number of alphas in that bin.
Alphas	Time since start of run (in seconds) and energy (in MeV) for every alpha.
Alpha Time-series	End time of bin (in seconds) vs. number of alphas in that bin. Same as Counts plot in Main Panel.
Emissivity	End time of bin (in seconds) vs. emissivity at that time (in $\alpha/cm^2/h$). Final bin is the final emissivity. Same as Emissivity plot on Main Panel.
Analysis Results	Analysis results of every event in the run. Includes event number, trigger time, event class, Anode amplitude, Anode risetime, Anode energy, and Anode timing parameters. (All of these explained more in AAE section of the User Manual.)

Table I: Exported files and their contents.

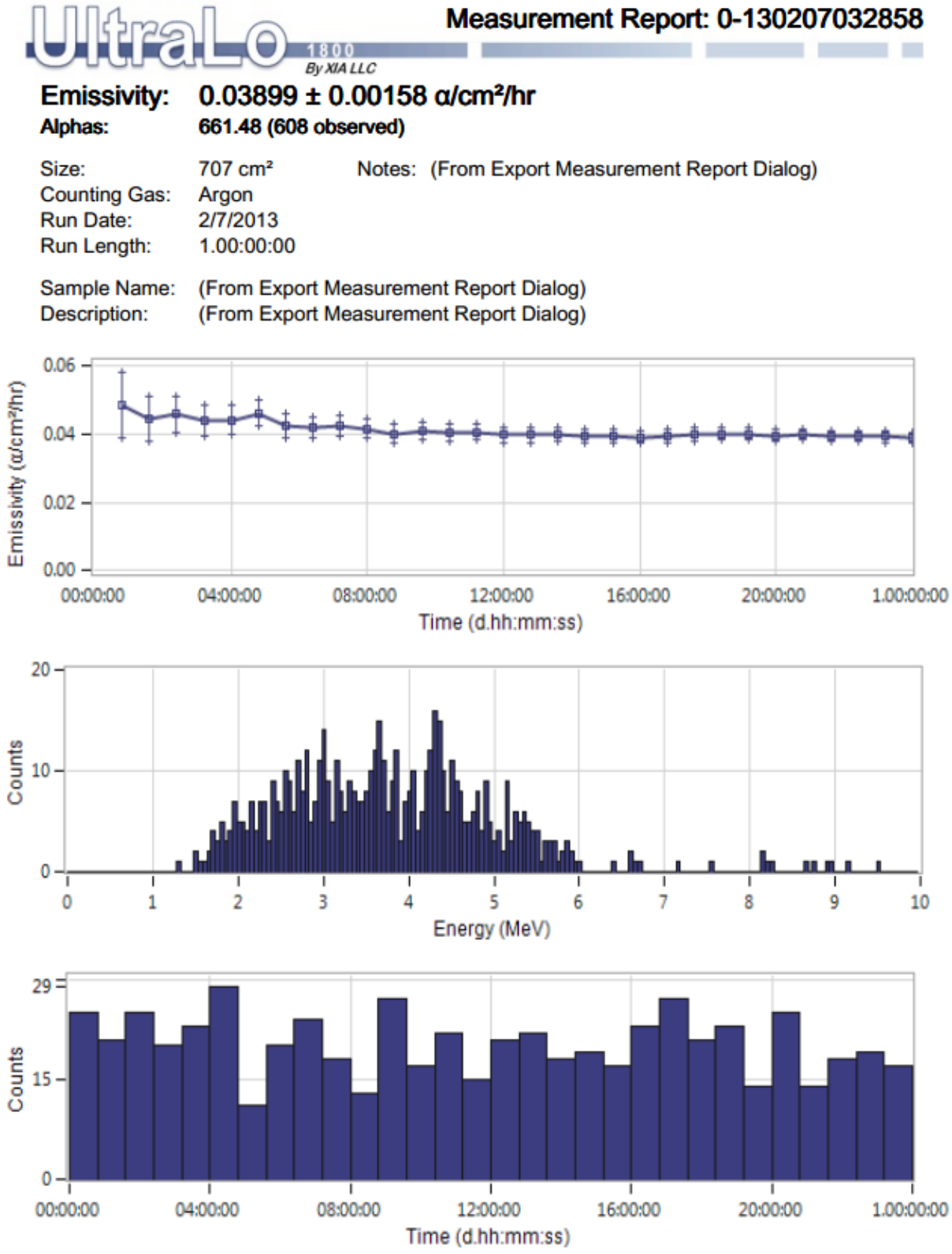


Figure VI-20: Sample of a run report.

VII. Troubleshooting

A. General Steps

There are a few techniques that are generally useful for troubleshooting the UltraLo-1800, regardless of the problem. These techniques will allow you to diagnose and/or solve many of the issues you will encounter during routine use of your counter.

The first technique is tremendously useful for electronics in general, and that's power cycling. This is a fancy term for turning a device off and then back on. This simple technique will solve many issues, and should be your troubleshooting technique of first resort. To power cycle, perform the following steps:

1. If CounterMeasure is open, close it.
2. Turn off the power switch on the support box.
3. Wait about 30 seconds for the high voltage to drain.
4. Turn the power switch back on.
5. Restart CounterMeasure.
6. Check to see if the problem is resolved.

B. Noise Debugging

To aid in the troubleshooting process CounterMeasure has a built-in **Diagnostic Panel** that is very powerful for troubleshooting sources of unwanted noise. A common technique to make sure the counter is operating well is to take traces at several time steps, from high to low, to see if any obvious oscillations appear in the trace, or any frequency peaks appear in the FFT. Taking traces at 400, 100, 10, 1, and 0.125 µs sampling intervals will often reveal noise sources. For instance, **Figure VII-1** shows a trace that has a very large peak at 60 Hz, as well as many harmonics. An FFT like this usually indicates that ambient room light is making it into the electronics chamber. In general no peak in the FFT spectrum should have a height above 1.000, and the peak-to-peak values of the ADC traces (at large time steps) should be less than 40 ADC, and at low time steps the traces should look fairly flat (examples shown below). Interpreting traces takes experience. To build an intuition for what normal operation looks like, take some traces before each run, especially in the beginning as you are learning to use the UltraLo-1800. This will also allow you to find abnormal conditions more quickly!

Finally, one thing you absolutely do not want to do without guidance is remove the side panels or electronics panel of the detector. The electronics inside are very sensitive, and there are exposed High Voltage nodes in certain locations. Only perform this maintenance under the guidance of an XIA technician.

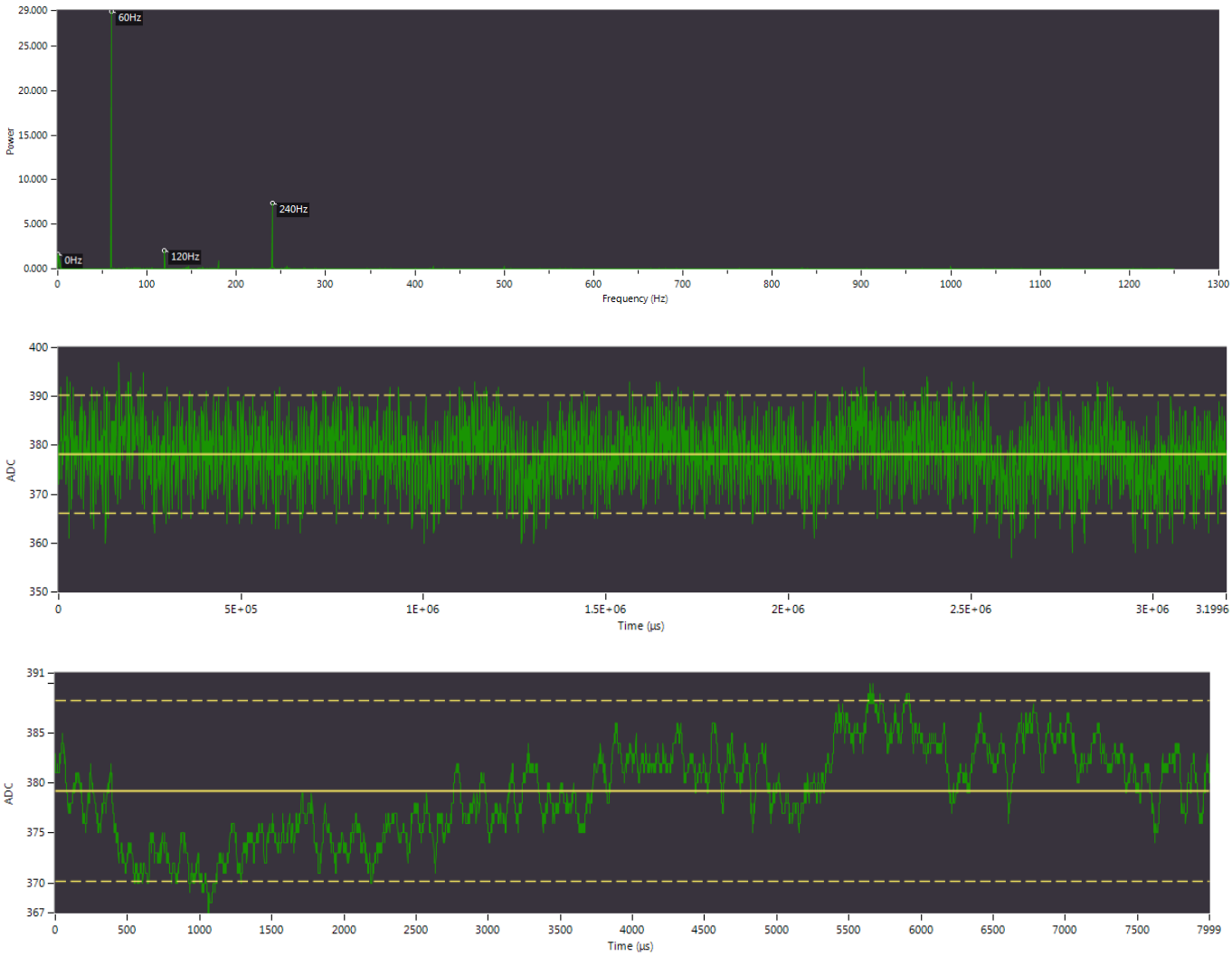


Figure VII-1: TOP: An ADC trace with 60-Hz peak and harmonics. MIDDLE: A typical trace at 400 µs time step. BOTTOM: A typical trace at 1 µs time step.

C. CounterMeasure Troubleshooting

CounterMeasure, being the interface to a technically complex and intricate detector system, may sometimes appear inscrutable or behave in unexpected ways. This section will allow you to debug any issues you might have with the software so you can get back to counting.

1. Can't Start a Run

Sometimes CounterMeasure won't let you start a run, almost always by disabling the Run Control Button. There are a two main reasons it will do this. The most likely is that the software didn't connect to the counter. If the "disconnected" icon is present near the status icons (see Figure VII-2) then this is your problem. See **Can't Connect to Counter** for how to troubleshoot this. The next most likely cause is that the tray is either all the way open or not fully closed. If the tray is open, close it. If it appears to be closed, try running it out, then back in. (For information on tray operation, see **Tray Control Button**.)

Figure VII-2: Disconnected icon.

2. Status Icons Red

There are three **Status Icons**, and they each turn red for a specific reason. If the HV or Gas icon is red, it means that the HV or Gas (respectively) is outside of normal operating range. If the Chassis icon is red, it means that the counter is tilted at a fairly sharp angle (usually because the upper chamber is opened). To fix a red Chassis icon, simply close and latch the counter. Typically all that's required to fix a red HV or Gas icon is to start a run, this will automatically ramp the HV and Gas to where they should be. If CounterMeasure is unable to ramp them to the correct value, it will generate a warning message. If the gas cannot be ramped it's usually due to inadequate gas pressure being supplied to the support box. Check your gas supply and make sure it's supplying 21 PSI. If the HV cannot be ramped, contact XIA support.

3. CounterMeasure is Frozen

Sometimes CounterMeasure will get into a state where it cannot continue normal operation, and occasionally cannot even be normally closed. If this happens simply open the Task Manager (via Ctrl+Alt+Delete), click on CounterMeasure, and click "End Task". Once CounterMeasure is closed, try to restart it. If it fails to connect, see **Can't Connect to Counter** for more troubleshooting information.

D. Counting Issues

1. Can't Connect to Counter

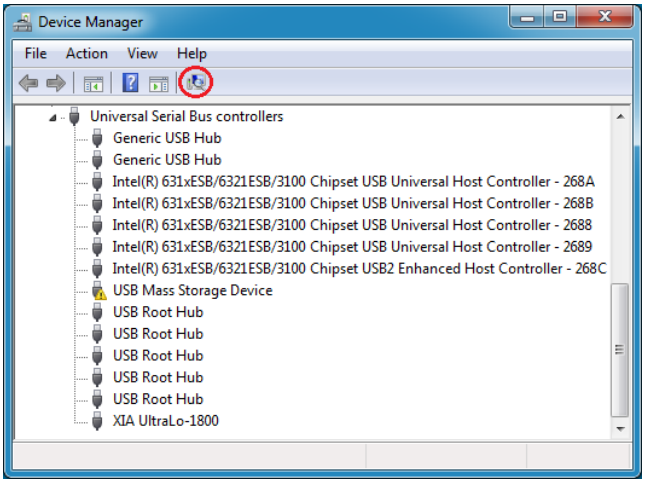

Device Manager
File Action View Help
Universal Serial Bus controllers
Generic USB Hub
Generic USB Hub
Intel(R) 631xESB/6321ESB/3100 Chipset USB Universal Host Controller - 268A
Intel(R) 631xESB/6321ESB/3100 Chipset USB Universal Host Controller - 268B
Intel(R) 631xESB/6321ESB/3100 Chipset USB Universal Host Controller - 2688
Intel(R) 631xESB/6321ESB/3100 Chipset USB Universal Host Controller - 2689
Intel(R) 631xESB/6321ESB/3100 Chipset USB2 Enhanced Host Controller - 268C
USB Mass Storage Device
USB Root Hub
USB Root Hub
USB Root Hub
USB Root Hub
USB Root Hub
XIA UltraLo-1800

Figure VII-3: Device Manager with "Scan for Hardware Changes" button circled in red.

If CounterMeasure cannot connect to the counter (diagnosed as starting with the "Disconnected" icon present (Figure VII-2)), the most likely cause is that the counter is powered off, or the USB cable has come unplugged. Check that the counter is powered on and the USB cable is connected. If they both are, open the device manager (by going to the Windows Start menu, clicking Control Panel, and then clicking Device Manager) and check under "Universal Serial Bus controllers". If "UltraLo-1800" appears in this section, then everything should be working properly. If it's not, try clicking the "Scan for Hardware Changes" button (see Figure VII-3). If this turns up nothing, or if the UltraLo-1800 only shows up with an error icon, try cycling the power switch on the support box off and then back on. If you still cannot connect to the counter, please contact XIA support.

2. Counting Stops During Measurement

If counting stops during a measurement the most likely causes are detector power issues or USB connection failures. Especially if the counter is located in a busy lab the USB cables can come disconnected and cause interruptions. Further, temporary power outages, even if they're very fleeting, can also cause communication issues. (If a stable power line is available, using it will help prevent power dips from causing problems.) If CounterMeasure experiences either interruption while running, it will stop the run and display an error message (see Figure VII-4). Left unattended in this state, CounterMeasure will attempt to reconnect automatically, and if the interruption was temporary it will re-establish the connection. However, CounterMeasure won't restart a run, and the error message will continue to be displayed to alert you to the issue. To verify that the counter is connected, check for the "Disconnected" icon (Figure VII-2).

If CounterMeasure isn't able to reconnect automatically, follow the troubleshooting steps outlined above in **Can't Connect to Counter**. Finally, if you experience counting stoppages that cannot be explained by interruptions in the power supply or USB connection, or particularly frequent stoppages, please contact XIA support.

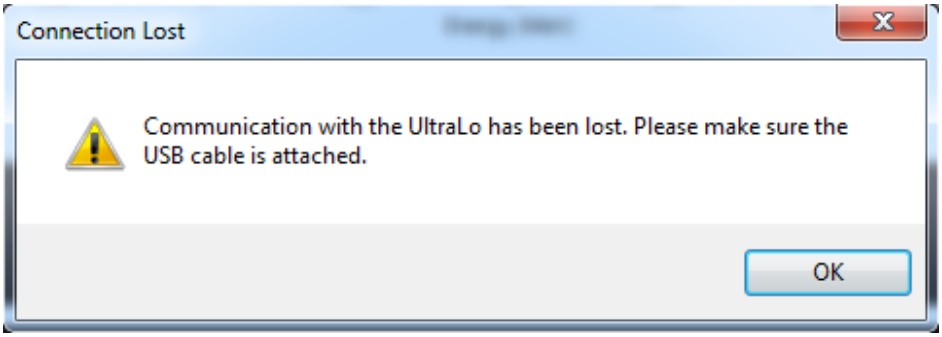


Figure VII-4: Error message when communication is lost.

3. Noise on Traces

The most common cause of traces with excess noise on them (see Figure VII-5) is electrical noise. This can come from a variety of sources, but a few are more common than others. One potential source is a noisy ground connection, which can happen if the ground connection to the UltraLo is shared with other large machinery, especially large electrical switches. It is very important to make sure that the UltraLo is connected to a quiet ground. If you start seeing noise suddenly, a change in the ground environment may have occurred. Try a different outlet and consult your facilities managers to see if something has changed in the electrical system.

There is also a possibility that noise can be generated internally. If the counter has been moved recently, connections may have loosened. If you suspect this is the case, contact XIA at support@xia.com and we will assist you with debugging.

4. Excessively High Sample Emissivity

If a sample has a higher emissivity than you expected, there are a few things to check. First, look at the emissivity versus time plot, if there's a large decrease throughout the run it's possible you had radon contamination (see **Radon**). In that case, measure the sample again and the measurement should be accurate. If there's no transient activity, check the analysis panel to see if there's an excess number of events. If there is, see **Excess Events** for more troubleshooting tips. If everything about the run looks normal but its emissivity is higher than expected, it's likely that the sample is simply more radioactive than expected.

5. No Alphas

If no alphas show up during a run, but there are other events, there are a few different things that could be happening.

a) Moisture

The most likely reason for not seeing any alphas while other events are occurring is that the moisture in the counter is too high. Water atoms in otherwise pure gas have the effect of increasing the drift velocity of electrons. This reduces the measured risetime and energy of alpha events, causing them to be misclassified (the effect is most apparent with risetime, and the events with low risetimes are classified as Midairs). See Figure VII-6 for an example of a run with significant risetime decrease due to excess moisture. In this case alphas will fail the midair/alpha cut and be classified as midairs. An

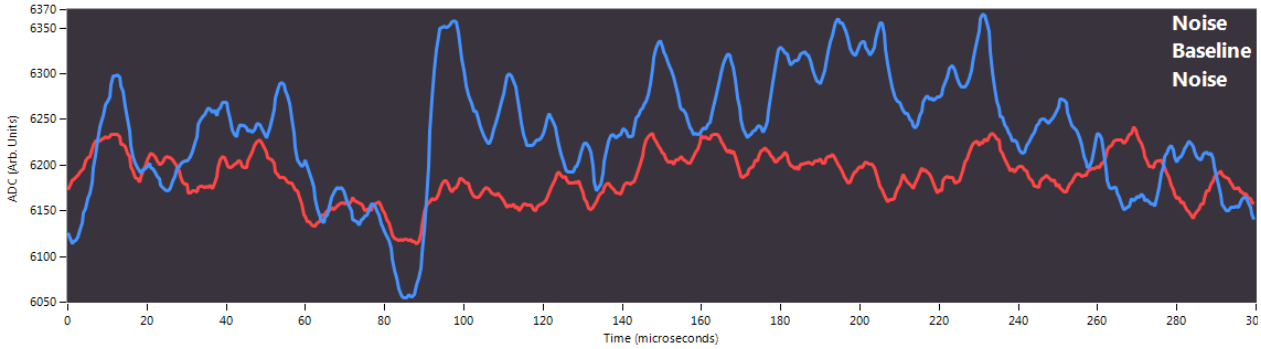


Figure VII-5: Noise trace.

inspection of your data's Anode Energy vs. Anode Risetime plot should tell you quickly if this is the case.

If your runs do have too much moisture, what could be causing it? There are a few things. If it's transitory you probably just need to purge for longer. To check for transitory moisture, you can use the **ROI Timeline** to filter out the early hours of a run and see if the risetimes as shown in the **Analysis Panel** are increasing with time. You can also check the moisture values in the **CounterMeasure Log** to see if they are changing with time. The moisture information is contained on a line that finishes "Moisture meter value = XXX ppm". Interpreting the value here is a bit tricky as every counter has its own baseline, and that baseline changes with time. Typically, values around 60 ppm are the highest consistent with normal operation. Significantly higher values (especially above 100 ppm) indicate the presence of excess moisture.

If the low risetimes and high moisture values persist throughout a run then it's possible that a source of moisture is in the counter or the gas line. Plastics absorb significant amounts of moisture and then outgas into environments with lower moisture (this is often observed in vacuum experiments), including the counting environment in the UltraLo-1800. If you're attempting to measure a plastic sample it may need a significant amount of time in a dry environment in order to measure (there are other tricky issues with measuring plastics, see **Dielectrics**). Likewise, if there are significant amounts of plastic tubing in the gas lines leading to the UltraLo-1800, that may cause increases in moisture.

Another cause for increased moisture levels is that the constituent plastics of the UltraLo-1800 may be outgassing. All UltraLo-1800's are outgassed prior to shipping, but if your counter goes for an extended period without gas flow it's possible for moisture to resorb. In this case keep the flow of clean gas undisturbed until risetimes return to normal, which should take only a few days.

Finally, it's possible, although quite unlikely, that the silicone rubber seal around the door to the sample tray may be leaking. The simplest test is a visual inspection of the seal. If there is nothing visually wrong, then ensure that the tray is closed, put your finger over the gas outlet on the rear of the counter (see **Counting Module**), and watch the pressure gauge. If the pressure rises smoothly and steadily up to 2 inches of water, the seal is performing adequately. If it doesn't, especially if it doesn't rise at all, there is some issue with the seal or door mechanism, and you should contact XIA support.

b) Electric Field Strength

If the electric field inside of the detector is not at the correct value then it won't be possible to

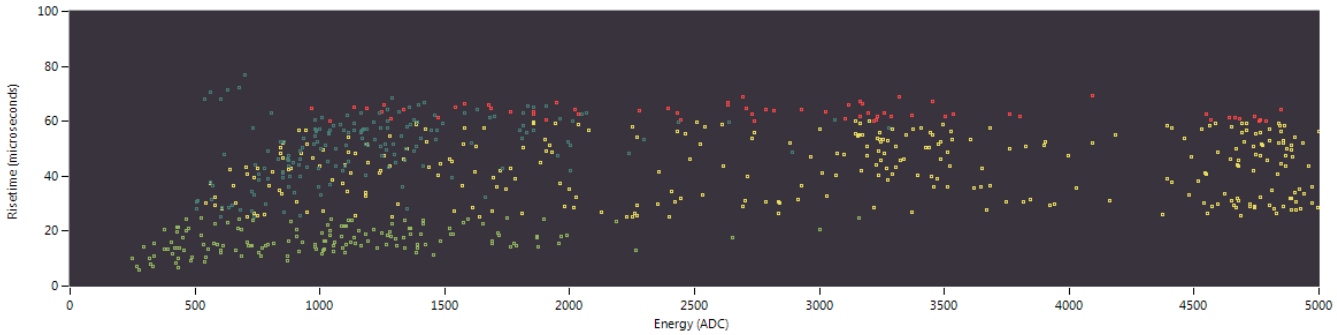


Figure VII-6: A run with high moisture. Note the large number of midairs.

observe any alphas. This shouldn't happen, but if it does CounterMeasure should indicate it with a red HV status icon, and the run will terminate with an error message. For more information on debugging red status icons, see **Status Icons Red**.

c) Oxygen

Oxygen is electronegative, and if it is present it will capture electrons in the active volume. This means that induced signals will be smaller than expected. By itself this effect will only decrease apparent alpha energy, but Oxygen is very rarely present in the active volume alone; it is usually accompanied by water vapor (see above). Getting rid of oxygen in the active volume follows the same procedure as water, but is even easier because oxygen isn't readily absorbed by plastics.

6. No Events

If there are no events present at all after several hours of running, there are several possibilities. The first thing to check is if the baseline voltage value in the active volume has drifted out of the range accepted by the electronics. This can happen if the high voltage was ramped immediately before starting a run without a purge. To test for this simply stop the run and start another one. Other than baseline drift, the remaining possibilities to check are the same as in the "No Alphas" case above. If the counter is run filled with room air, for instance, it will likely see no events.

7. Excess Events

There are a number of causes of extra events. The following sections include reasons for excesses of all event types, as well as excesses of specific event types. Excess event types don't always indicate a problem, many times they are simply the result of the sample, or conditions in the counter that are easily rectified. But they can inhibit proper operation, so keeping an eye on typical event rates can help you notice changes and spot a problem early.

a) All Types

The most likely cause of a large number of events is excess noise in the environment, particularly from mechanical vibrations, which cause the inherent noise level in the system to increase dramatically. (The mechanism is that vibrations produce slight changes in the detector's capacitance, which generate changes in the output current of a similar size to our signals. See **Signal Generation** for more information.) Mechanical noise is usually very easy to spot, for an example see Figure VII-7. Additionally, mechanical noise will often cause many events to occur in rapid succession, and in that case scrolling through events sequentially in the Analysis panel will show streaks of these traces. Eliminating this noise will depend on the environment, in some cases it may be straightforward, in others it could be quite difficult. But the UltraLo-1800 needs a quiet environment to function properly, so eliminating sources of vibrations or physical noise is paramount. Finally, if these vibrations are strong enough they can even trigger a built-in accelerometer that will cause the run to stop.

b) Guards

Excess guards are typically caused by an unusually radioactive sample that extends under the guard, in which case you will also see an excess of alphas. But an excessive number of guard events can have other causes. Any contamination on the sidewalls, for instance, will do it, although this is very rare.

c) Midairs

Midairs are mostly caused by **Radon**. As such an excessive number of midairs usually indicates the presence of radon. This results in a spectrum with the characteristic peaks of radon. If radon is the culprit, the most likely source is emanation from the sample being measured. Try removing the sample, purging, and seeing if the signal remains. If it does, there may be radon contamination somewhere in your gas line or the counter itself. In this case please contact XIA.

If there are no characteristic radon peaks it could be that excess moisture is causing lowered risetimes, and alphas are showing up as midairs. For details on troubleshooting this scenario, see **Moisture**.

Finally, some percentage of cosmogenics show up as midairs (for more information on cosmogenics, see **Cosmogenics**). For information on troubleshooting excess rounds, see the next section.

d) Rounds

Rounds are caused by cosmogenic radiation, as detailed in **Cosmogenics**. Excess rounds implies excess cosmic radiation, which has no easy solution. If you see large numbers of rounds (~8/hour is normal at sea level) try moving the counter into a basement, if possible. At the moment adding more material above the counter is the only way to reduce the round rate. XIA is actively researching veto panel technology, and will alert our customers to any progress.

e) Noises

You can get a large number of “Noise” triggers if the thresholds are set too low. The thresholds are set in the diagnostics panel, and they control the level a trace needs to reach in order for

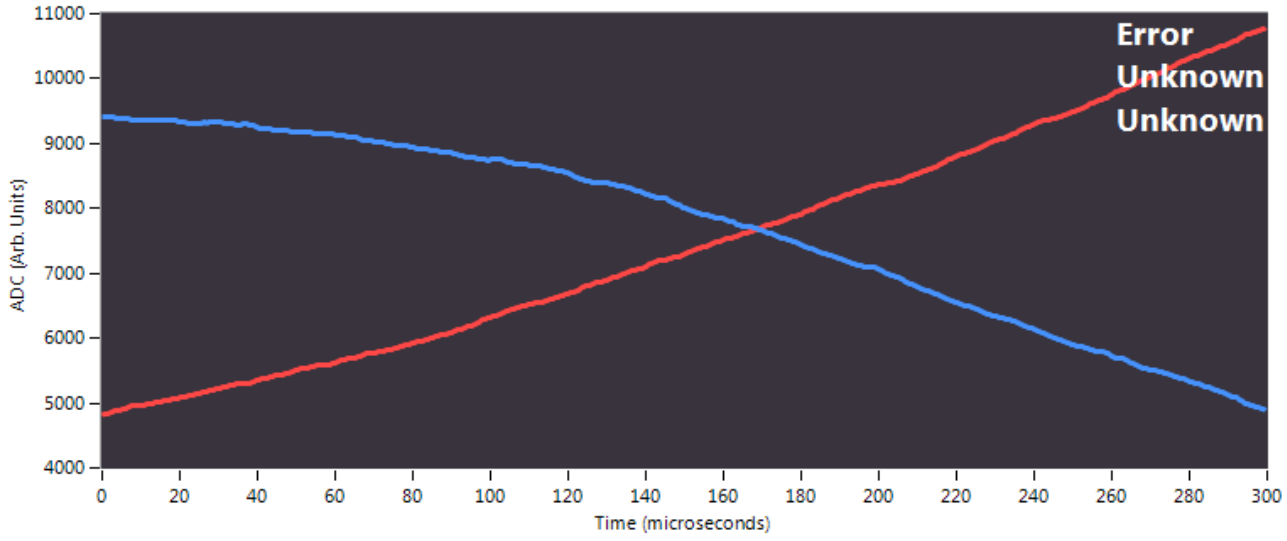


Figure VII-7: Event caused by mechanical vibration of the counter.

CounterMeasure to process it as a pulse. If that level is low, CounterMeasure will trigger on the noise inherent in the system, and this will produce quite a few triggers. Fortunately this is very easy to diagnose, as you can simply check the **Trigger Thresholds**.

A large increase in Noise events is also possible for various other reasons, including loose connections between high-voltage nodes. This typically only occurs if the counter has been moved or otherwise vibrated. If you have excess noise events with adequate thresholds, please contact XIA support at support@xia.com.

8. Non-Alpha Events

As was mentioned previously, mechanical vibrations are capable of causing erroneous events to appear in measurements (see **All Types** for more information on mechanical vibrations). The computed energy and risetime of those events will sometimes fall within the typical energy and risetime bands occupied by our various classifications, but most often they won't. Vibrations are easy to spot because the traces oscillate wildly and they rarely look like alpha pulses.

Occasionally the counter will see events whose origin is purely electronic (see Figure VII-8). It's not entirely clear what causes these events, but static charge buildup on insulators, especially when the insulator is the sample, is a prime suspect (see **Dielectrics**). These events are, in our experience, never categorized as alphas, but usually as Negative Charges or Noises. If you're seeing a very large number of them and you're not measuring an insulator, contact XIA at support@xia.com.

9. Large Drop in Emissivity During a Run

The most likely cause for a large drop in emissivity over the course of run is contamination from radon. See **Radon** for more information on how to tell if radon is present on your samples.

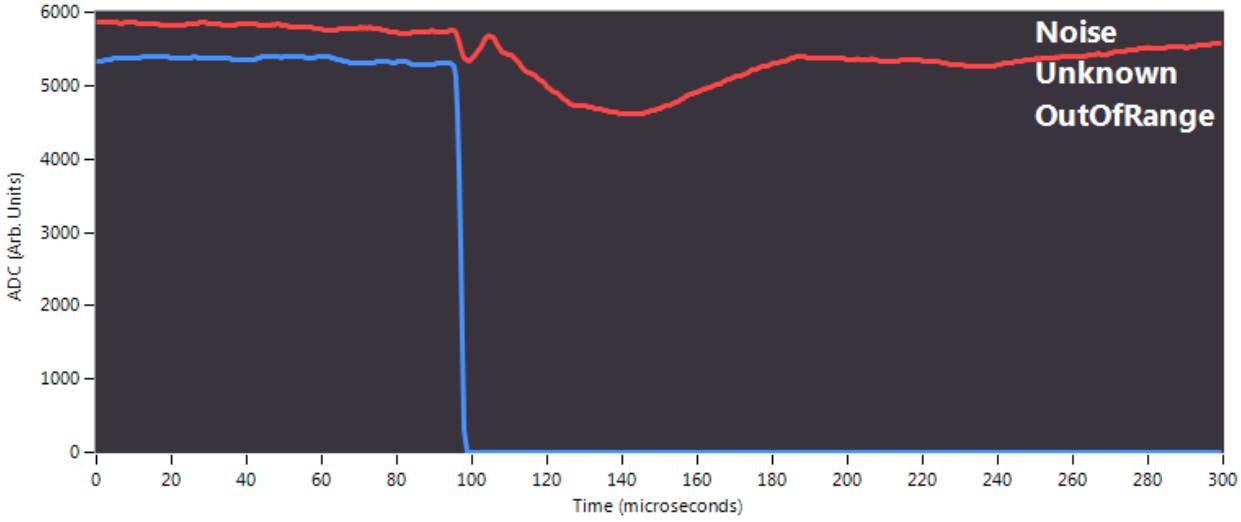


Figure VII-8: One type of noise event.

VIII. Alpha Analysis Engine

A. Introduction

The software responsible for analyzing and classifying traces is called the "Alpha Analysis Engine", or AAE for short. The goal of AAE is to identify alphas, and it does this by progressively eliminating non-alpha events based on their characteristics. If an event passes every elimination test (such tests are typically called "cuts"), it is classified as an alpha.

B. Overview

In brief, the algorithm takes the following steps:

1. Prescreener: A quick fit to both traces that classifies them individually based on amplitude, if the resulting classification pair indicates a potential alpha, pass trace to Level One. If there's no potential alpha, the analysis of the event is finished.
2. Level One: A more robust, least-squares fit of both traces with cuts based on amplitude, risetime, and other timing results. A test for "induction" on the traces is performed, and if any is detected, pass to Level Two. If none is detected, the analysis of the event is finished.
3. Level Two: Another least-squares fit, but now modeling a pulse with "induction". Performs "add-back" to get more accurate results on the anode, and applies Level One cuts again.

C. Classifications

Each trace is given a classification, and most pairs of trace classifications directly result in an event classification, but some require more detailed analysis (Level One as detailed in the previous section). A chart showing how trace pairs correspond to event types is shown in Table II. Figure VIII-1 shows examples of each trace classification. The following text explains all trace and event classes.

The list of trace classification is:

- Alpha-like: These traces have a large, positive step-like shape, similar to those generated by alphas.
- Baseline: These traces are flat compared to the large alpha pulses and did not cause the channel to generate a trigger signal.
- Noise: These traces are also quite flat, but have some feature which caused the channel to trigger. These can be caused by random fluctuations in the baseline. These fluctuations are inherent in the counter, but can be caused by external influences as well.
- Negative charge: These traces exhibit a negative step. They are relatively rare and are caused by electrical noise, or by large negative noise fluctuations.

And the list of event classifications is:

- Trace pairs that don't require Level One analysis:
    - Sidewall: An event with significant energy on the guard electrode. (Occasionally a pulse will be classified as a sidewall after Level One, but most sidewalls are classified by the prescreener.)
    - Negative Charge: An event with a negative charge classified trace on either channel.
    - Noise: An event with noise or baseline on the anode and guard.

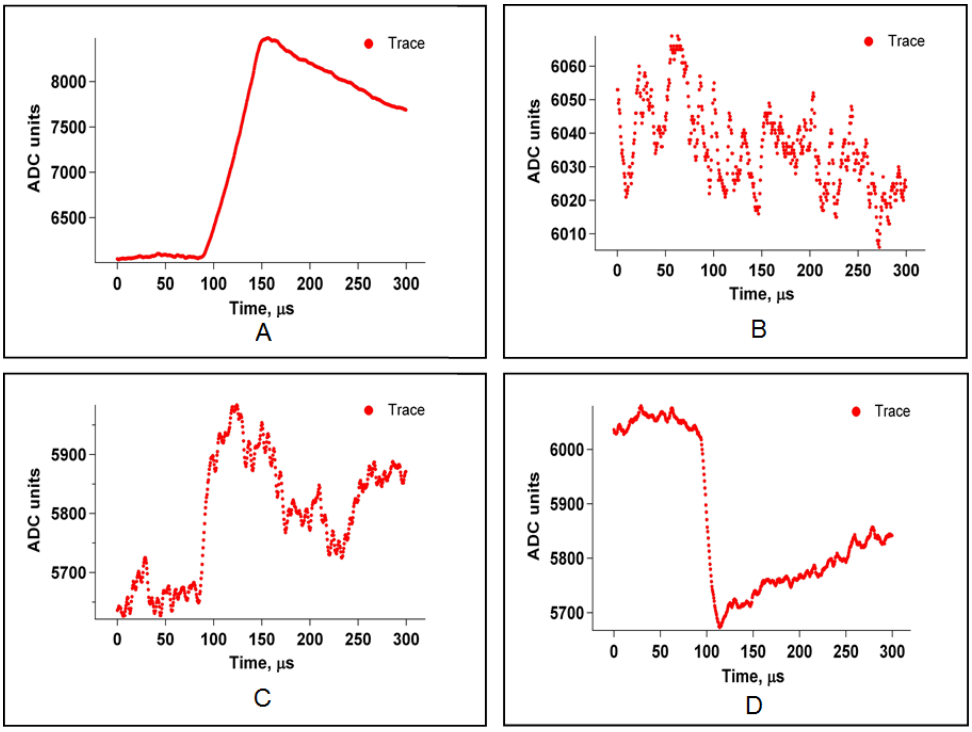


Figure VIII-1: Trace classifications. A: Alpha-like; B: Baseline; C: Noise; D: Negative charge

Anode\Guard	*Baseline*	*Noise*	*Negative Charge*	*Alpha-like*
Baseline	Noise Event	Noise Event	Neg. Charge Event	Sidewall Event
Noise	Noise Event	Noise Event	Neg. Charge Event	Sidewall Event
Negative Charge	Neg. Charge Event	Neg. Charge Event	Neg. Charge Event	Neg. Charge Event
Alpha-like	Further Analysis	Further Analysis	Neg. Charge Event	Sidewall Event

Table II: Table of anode and guard trace classification pairings and the resulting event classification. Anode classifications are shown in red, Guard in blue.

- Trace pairs that require Level One analysis:
  - Alpha: If an event is classified as an alpha that means that, to our best ability to discriminate, it was caused by an alpha particle emission from the sample area under the anode electrode.
  - Midair: Midairs are events whose risetime is too short to be an alpha, but too long to be a ceiling. They are caused by interactions in the bulk of the counting gas, mostly from radon but also from cosmic rays.
  - Round: Rounds are events whose peak is too rounded to be caused by alpha particle. These are the result of particles that can cause longer ionization tracks, most likely cosmic rays.
  - Ceiling: An alpha decay emanating from the electrode.

IX. Counting Various Sample Types

A. Undersized Samples

Whenever background subtraction (see **Undersized samples**) is necessary, it is advantageous for the background to be as low as possible. The stainless steel tray of the UltraLo-1800 is very good for many purposes, but its emissivity of approximately 0.0030 alphas/cm^2/hr makes it an undesirable background for ultra-low-activity samples. Because of this, we recommend using a tray liner to cover the tray, blocking its alphas while emitting few of its own.

The ideal liner material will vary depending on purpose. Silicon is very low emissivity, but difficult to work with and often impractical. Most plastics are low-emissivity, but plastics have many measurement difficulties (see **Dielectrics**). The liner used in XIA's counting lab is conductive Teflon, available from XIA. This material has an emissivity of approximately 0.0010, several times lower than the steel, and is quite durable, lasting many months taped to a tray. This Teflon is the best commercially available liner XIA has been able to find to date.

B. Dielectrics

Measuring dielectrics correctly is very difficult. The first difficulty is that plastics tend to absorb water, some much more so than others. This absorbed water will then outgas in the very dry environment of the counter. This outgassed water can affect measurements by causing risetimes to decrease, as described in **Moisture**. The only way to measure a sample that is outgassing is to wait for it to finish. How long this takes depends on many factors, including the plastic type, the humidity it has been exposed to, and the temperature. Outgassing can be done either in the counter itself or in an external glovebox. Testing for the presence of outgassing requires either a Moisture Meter or some kind of alpha source. With a Moisture Meter testing is simple, just put the sample into the counter and see if the Moisture Meter reads above normal background. Testing with a source requires putting the source on the sample and taking a measurement, which is likewise simple, but it introduces the risk of contamination. If the resulting measurement shows normal pulses, there is no outgassing. If the pulses have a low risetime, there is likely outgassing.

The second difficulty with dielectrics is static charge buildup on the surface of the dielectric. This problem is exceptionally thorny. Static charge on dielectrics seems to lower alpha energies, as well as reduce apparent emissivities. While we've had some success with anti-static guns intended for eliminating static from vinyl records, it has been limited. Testing for static requires a source, and is done exactly as above to test for outgassing. The main difference is that you're looking for low energies and emissivity instead of risetimes. See Static Buildup and Measuring Insulators in the UltraLo for a more detailed look at this subject.

C. Thick Samples

While the UltraLo-1800 is designed to measure very thin samples, such as silicon wafers, it is capable of measuring thicker samples. However, if the sample is greater than about 1/16 of an inch thick, it can start to cause strange results by decreasing the distance electrons drift (and therefore decreasing

risetime, see **Theory of Operation**). This is especially problematic when the sample is not flat as any features will cause local distortions.

The only solution to samples with features on their surfaces is careful measurement. However, the UltraLo-1800 does have the ability to adjust the height of the tray in order to measure thicker samples. Adjusting the blocks under the sample tray to move thick samples closer to the intended distance from the electrode makes measurements on them very simple. See **Adjusting the Tray Height** for details on how to adjust the blocks.

D. Bulk Sources

Bulk sources are materials whose alpha emitters are distributed throughout their entire volume. This results in a broad tail of events going down to low energy from the main peak, the main peak being from the alpha emissions at or near the surface. The UltraLo-1800 will count these types of materials well, but it is only capable of measuring the emissivity, that is the amount of radiation leaving a surface. This is not the same as the rate of decays throughout the entire sample. Additionally, as with any counter there is a cutoff energy below which the UltraLo-1800 isn't sensitive. You can see this in Figure IX-1, where no alphas below approximately 1.5 MeV (or 750 ADC) register in the detector. The energy at which about half of events register is around 2.5 MeV. The cutoff energy is dependent on the anode trigger threshold, the cutoffs cited here are based on measurements taken at the recommended threshold value of 175. Additionally, the exact cutoff at a given threshold will vary per counter. With surface sources this isn't an issue as no alpha particle has an energy that low, but with bulk sources it means that the detector won't see events originating below a certain depth. Finally, with a bulk source the alpha energy spectrum will be "smeared" down to the cutoff energy due to alpha particles emitted from the bulk losing energy as they pass through the sample material.

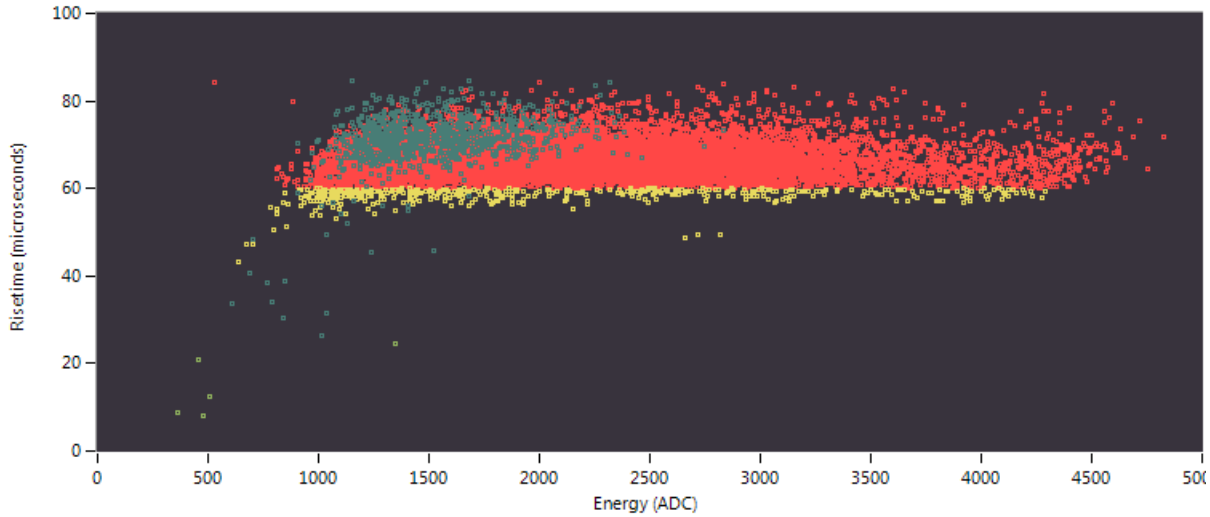


Figure IX-1: A bulk source with no alphas below about 1.5 MeV (750 ADC).

E. Tiling Samples

Sometimes a sample will be very small, but many identical samples are available. When this is the case tiling the samples on the tray can provide more complete coverage and therefore better results. This is easily accomplished with identical squares or rectangles, as they can simply be pushed together to cover the surface of the tray. For other shapes or samples where each piece is slightly different, other solutions are required. Often overlapping the samples is the best course of action. Keep in mind that the UltraLo works best with as flat a surface as possible, and so keep vertical disruptions to a minimum for the most accurate measurement. For an example of a tiled sample, see Figure IX-2.

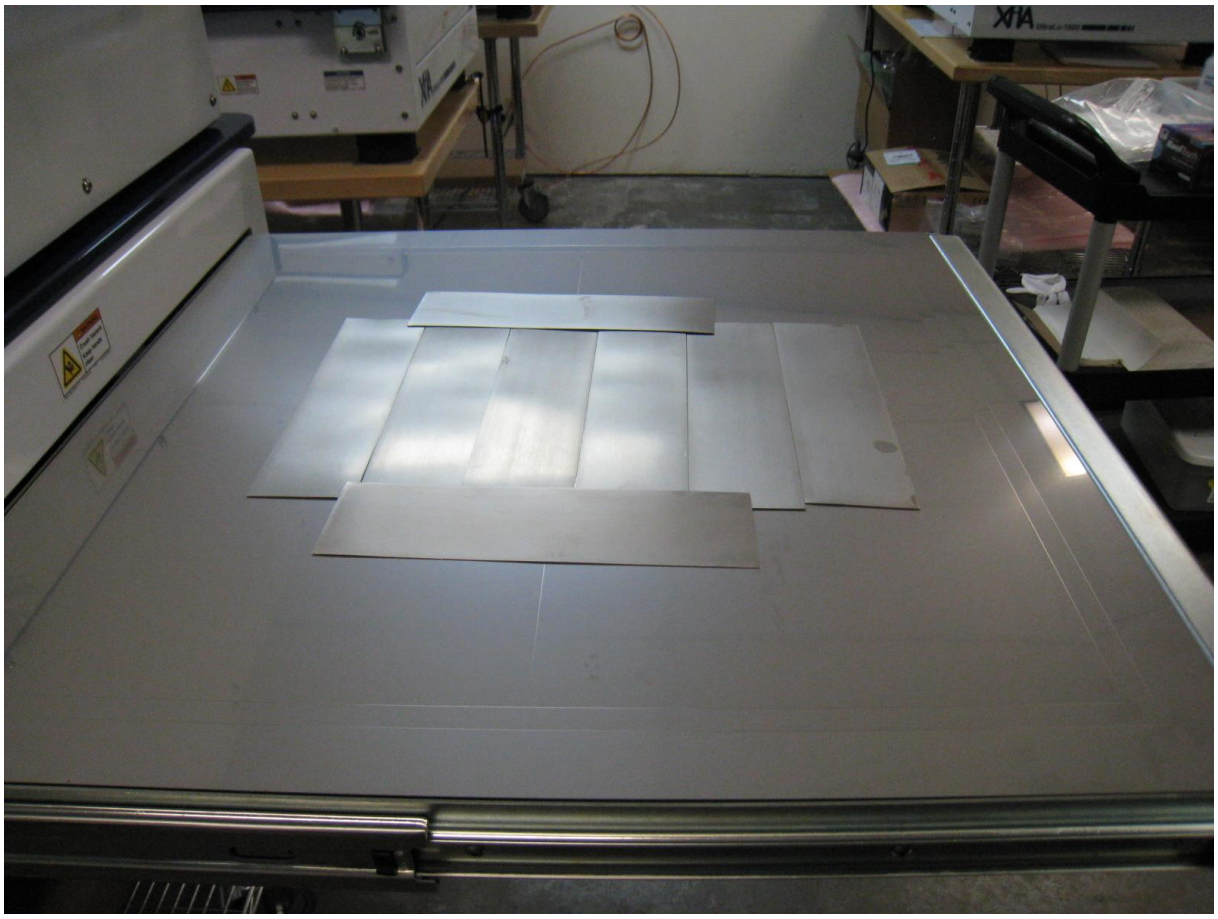


Figure IX-2: Irregularly shaped pieces of metal tiled to cover the Wafer configuration.

X. Appendix

A. Counter Efficiency

The UltraLo-1800's guard electrode, while critical for detecting sidewall events and eliminating background counts, also causes the counter to detect alpha particles emitted from the sample with less than 100% efficiency. Specifically, if an alpha particle is emitted from the sample and any portion of its ionization track lies under the guard electrode, then that charge will be collected by the guard electrode, producing an "alpha-like" output signal from the guard preamplifier. Meanwhile, the rest of the ionization track is collected on the anode electrode, also producing an "alpha-like" output signal from the anode preamplifier. Unfortunately, this pair of signals cannot be distinguished from a true sidewall event (please refer to Figure II-6, where a sidewall α3 and α4 from the edge of the sample produce similar output pulses). The event is therefore classified as a "sidewall" and rejected. (See Table II for more information on trace classifications and resulting event classifications.)

The probability of ionization tracks crossing the electrode-guard boundary clearly depends on both how close the point of emission lies to the boundary and how long the track is. Right at the boundary fully 50% of emissions will cross under the guard, for example, while if a track is 3 cm long and it's emitted 4 cm from the boundary, its chance of crossing is clearly zero. Since track length varies with alpha particle energy, counting efficiency is clearly energy-dependent. For a given energy (track length L_E) the counting efficiency at each location within the sample area is then just that fraction Ω_E of 2π solid angle where L_E crosses the boundary – a straightforward geometric calculation. The counter's total efficiency $\langle\Omega_E\rangle$ at that energy is then the average of Ω_E over the full sample area. We have carried out these computations analytically and verified them with both Monte Carlo simulations and measurements with a calibrated check source. The results are shown in the table below.

CounterMeasure then uses these efficiencies to correct the counter's output for "lost" alpha particles. In principle this could be done in two ways. The classical method would be to wait until the measurement was complete, bin the results by energy, and then divide each bin result by the efficiency at that energy to obtain a corrected number of alpha particles. However, since we want to be able to always display a corrected emissivity value as the count progresses, each time an alpha particle is detected its energy E is measured and the quantity $1/\langle\Omega_E\rangle$ is added to the "corrected" number of alphas observed, and used to compute the overall emissivity from the sample.

E_α (MeV)		Efficiency Corrections $\langle\Omega_E\rangle$	
Energy Range	**<Avg>**	*Full Config.*	*Wafer Config.*
0 ≤ E < 1	**0.5**	1.0000	1.0000
1 ≤ E < 2	**1.5**	0.9816	0.9740
2 ≤ E < 3	**2.5**	0.9672	0.9542
3 ≤ E < 4	**3.5**	0.9497	0.9306
4 ≤ E < 5	**4.5**	0.9290	0.9035
5 ≤ E < 6	**5.5**	0.9052	0.8736
6 ≤ E < 7	**6.5**	0.8790	0.8424
7 ≤ E < 8	**7.5**	0.8505	0.8102
8 ≤ E < 9	**8.5**	0.8188	0.7769
9 ≤ E < 10	**9.5**	0.7876	0.7467

Table III: UltraLo-1800 Efficiency Corrections

For example, assume that, in the 'Full' configuration, we observe 1 alpha in each of the 1 MeV bins (1-2, 2-3, up to 10), shown in the table above. These 10 observed alphas are then corrected to 11.09.

Note that this correction is based on the statistics of radioactive decay and is most accurate for large numbers of alphas. For very small numbers of alphas there may or may not have been a "missed" event, as implied by the correction factor. However, the corrected number of alphas is still the best unbiased estimate that we can produce of the true emissivity.

It is important to note that these corrections assume that your sample covers the entire active area (either wafer or full). If you conduct a measurement with an undersized sample, this correction is *still applied* and can lead to discrepancies between corrected measurement results and calibrated sample values. The differences are particularly noticeable when using a calibrated check source that is essentially a point source.